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APPLYING THE THEORY OF CONSTRAINTS (TOC)
TO THE COMPONENT SECTION
OF NAVAL AVIATION DEPOT (NADEP), NORTH ISLAND

by

LCDR David Joseph McNamara
and
CPT Mark Anthony D'Amato

December 1992

Thesis Advisor: Dan Trietsch
Co-Advisor: Alan W. McMasters

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Eliyahu M. Goldratt first introduced the Theory Of Constraints (TOC) as a means of managing and synchronizing repetitive manufacturing operations. This thesis explores the extent to which TOC management principles can be applied to a repair job shop within the Naval Aviation Depot (NADEP) at North Island, San Diego, California. This thesis begins with a description of TOC and an overview of how the NADEP is organized. It continues with a description of how Shop 93302 (hydraulic component repair) operates in the depot. Against this backdrop, we discuss the extent to which TOC can be used to evaluate current repair policies and procedures within this shop. We offer some ideas and suggestions for changing and improving existing operations and the probable effect these changes will have on production, inventory, and repair turn-around-time (TAT). We conclude that TOC is an effective means of implementing and focusing continual improvements in Shop 93302 and ultimately in the depot as a whole.

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TO THE COMPONENT SECTION
OF NAVAL AVIATION DEPOT (NADEP), NORTH ISLAND

by

David Joseph McNamara
Lieutenant Commander, United States Navy
B.S., University of Massachusetts, 1980

and

Mark Anthony D'Amato
Captain, United States Army
B.A., Kent State University, 1981

Submitted in partial fulfillment
of the requirements for the degree of

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from the

NAVAL POSTGRADUATE SCHOOL
December 1992

Authors: _____
David Joseph McNamara

_____
Mark A. D'Amato

Approved by: _____
Dan Trietsch, Thesis Advisor

_____
Alan W. McMasters, Co-Advisor

_____
David R. Whipple, Chairman,
Department of Administrative Sciences

ABSTRACT

Eliyahu M. Goldratt first introduced TOC as a means of managing and synchronizing repetitive manufacturing operations. This thesis explores the extent to which TOC management principles can be applied to a repair job shop within the Naval Aviation Depot (NADEP) at North Island, San Diego, California. This thesis begins with a description of TOC and an overview of how the NADEP is organized. It continues with a description of how Shop 93302 (hydraulic component repair) operates in the depot. Against this backdrop, we discuss the extent to which TOC can be used to evaluate current repair policies and procedures within this shop. We also offer some ideas and suggestions for changing and improving existing operations and the probable effect these changes will have on production, inventory, and repair turn-around-time. We conclude that TOC is an effective means of implementing and focusing continual improvements in Shop 93302 and ultimately in the depot as a whole.

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I. INTRODUCTION

A. BACKGROUND

This thesis will investigate Naval Aviation Depot (NADEP) North Island's production planning and inventory control systems. With the current DOD trend toward military downsizing and concurrent emphasis on increasing productivity and quality while decreasing costs, NADEPs are eager to apply the latest proven production techniques.

The "Theory of Constraints" (TOC) or "Bottleneck Management" has been widely demonstrated as applicable to a manufacturing facility. It has shown merit in both government and business applications. We will attempt to further establish TOCs benefits in an industrial repair or job shop environment.

B. OBJECTIVE

The objective of this thesis is to attempt to apply the concepts of TOC to the current production planning and inventory control systems within the Component Section of NADEP, North Island (NI), CA.

C. RESEARCH QUESTION

Primary Research Question: Is the Theory of Constraints a feasible managerial technique for NADEP NI to use in

managing their operation? Can the application of TOC provide any benefits for an industrial repair activity?

Subsidiary Questions:

1. Does the concept of TOC provide a framework for continuous improvement that will work at a NADEP?
2. Does TOC include sufficient management techniques to optimize productivity, or are there any other practices that would be useful?

D. SCOPE, LIMITATIONS AND ASSUMPTIONS

An important aspect of the TQM revolution that has swept private industry and government is Dr Demings fifth management principle; that of "constantly and forever improving the system of production and service". The Theory of Constraints is a specific set of managerial and production guidelines that can be used to implement this principle, while prioritizing the improvement projects. This paper will focus upon the Theory of Constraints as it applies to NADEP NI's Component Section. Specifically, we identify an actual constraint within the Component Section's production flow, and provide corresponding recommendations to increase capacity at this constraint. However, a cost/benefit analysis of the proposed recommendations will not be provided.

E. METHODOLOGY

First, we conducted a thorough literature review on the Theory Of Constraints (TOC) as well as other popular production management theories. We also reviewed the current

regulations, guidelines, policies and procedures used at NADEP North Island.

Next, we made on-site visits to the depot to observe operations and interview key personnel. We used the depot's management information systems as a key source of data for the thesis. We also visited NADEP Alameda who already uses TOC in some of its operations.

Finally, we applied TOC to the Component Section to: (1) determine the extent to which it can be used and (2) determine the potential benefits of using TOC.

F. ORGANIZATION

There are six remaining chapters. Chapter II describes the key concepts of the "Theory of Constraints" (TOC), which will be drawn upon in later analysis. Chapter III describes the current organization of NADEP NI. Chapter IV details the current planning and scheduling of component repair at the Depot. Chapter V looks at Production Control and how jobs currently flow through various shops. Chapter VI looks specifically at one component (F/A-18 Horizontal Stabilizer Hydraulic Servo Cylinder) as it is processed through the NADEP. Chapter VII contains a description and analysis of an application of the Theory of Constraints to the Component Section at NADEP NI. Chapter VIII contains a summary of the thesis, conclusions and recommendations.

II. THEORY OF CONSTRAINTS

The purpose of this chapter is to highlight aspects of the "Theory of Constraints" (TOC) which will provide the rationale for analysis of component flow through NADEP North Island. Managerial philosophy and software based on Eliyahu Moshe Goldratt's "Theory of Constraints" has been used to some extent since the 1980's by numerous Fortune 500 corporations including GE, Westinghouse, Ford, RCA, GM and M&M/Mars.(Melton, 1986) (Bylinski,1983) Most of the available examples of TOC application involve manufacturing operations. However, TOC is fully applicable to the job shop environment of a Naval Aviation Depot.

The nature of the repair floor is similar to that of a manufacturing shop floor. In repair, an item progresses through a series of workcenters where people and machines are staged to perform unique operations in transforming the item. TOC is concerned with the flow of materials through the shop floor resources (workcenters, workstations, people) and the ability of the resources to meet the demands placed on them. (TQM Division, 1990)

The TOC-based scheduling software packages "Optimized

Production Technology" (OPT)[1] and "DISASTER"[2] will not be discussed. However many references used herein have used OPT synonymously with TOC.

A. INTRODUCTION

> The market place today is more crowded, faster changing and more fiercely competitive than any time in history. The lifecycles of products are shortening; zero-defects is becoming the goal of quality; new machine technology is being introduced each year and systems to control production replace each other at an unprecedented rate. Clearly, something far greater than a few sporadic improvements is now needed. Indeed, the only way to secure and improve one's competitive position today is by instituting a process of ongoing improvement. What is required is a process which will, at any moment, identify clearly the area where an improvement will yield the maximum global impact. This process must enable an organization to achieve the maximum gain from such improvements, while simultaneously helping it to identify clearly the area where an improvement is needed and to quantify the impact. (Goldratt and Fox, 1986)

The process of securing and improving one's competitive position can no longer, espouses Goldratt, be monitored simply through the traditional financial measures of net profit, return on investment and cash flow. In fact, Goldratt has accused the "local measurement" of cost accounting of being "the number one enemy of productivity." (Goldratt, 1983) Goldratt proclaims that cost accounting makes an invalid assumption. The assumption being that the portion of

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[1] OPT was marketed by Creative Output Inc. in the early 1980's. At the time Dr. Goldratt was chairman of the board.

[2] Developed and released by Goldratt in the late 1980's.

manufacturing cost that is allocated to an individual product reflects its true cost. Additionally, "Standard costing of labor and machine efficiency diminishes a plant's total efficiency." (Goldratt 1983) "... at the period's beginning, plant production responds to cost accounting measurements, but as the end of the period approaches, global measurements force the expediters to split batches, overlap, go into overtime and push the goods out the door in order to get the sales on the books. After meeting the end-of-the-period crisis, the plant lapses back into its normal pattern." (Edwards and Heard, 1984)

An organization may have many means to achieve long term survival. Producing high quality products, increasing market share, developing technology and providing jobs do not necessarily guarantee the firm will meet its goal. It will prosper, however, only if the firm makes money. (Chase and Aquilano, 1989) Goldratt would add that the firm must make money now and in the future.

1. Measurements

Goldratt proposes a new way to measure system performance in meeting the firm's goal of making money now and in the future. The process of ongoing improvement should be measured at the operational level in the following areas: (Goldratt and Cox, 1992)

- Throughput - The rate at which the system generates money through sales.

- Inventory - All the money the system invests in purchasing things the system intends to sell.
- Operating Expense - All the money the system spends in turning inventory into throughput.

The above definitions are precisely worded. Throughput does not include finished goods inventory. There is no money generated by making a product that is not sold. (Also, inventory does include the purchase of a building or capital investment since the firm does eventually intend to sell or amortize these things.) Operating expense includes items that traditional accounting practice disregards, such as salaries. In this way a true global picture of the system performance can be derived. There will be nothing hidden from the bottom line.(Goldratt and Cox, 1992)

A positive impact on throughput means that throughput increases while a positive impact on inventory and operational expense means that these measurements decrease. TOC proposes that these "global measurements" be adopted at each organizational level by managers responsible for any decision that relates to the design, planning and scheduling of shop floor operations, production and/or distribution, including information systems. (Weston, 1991)

2. Constraints

A principal assumption of TOC is that there is always at least one bottleneck or in more general terms, constraint on each product or process. That constraint limits the firm's

revenue. Umble and Srikanth list plant capacity, market, availability of materials, logistics, management policies and work force behaviors as examples of constraints that can limit revenue. Those workcenters or workstations within the firm that have the least capacity relative to the demand placed on them are the constraints (assuming that demand exceeds capacity). A workcenter or machine with excess capacity is a non-constraint workcenter or machine. (Gardiner and Blackstone, 1991)

Constraints or bottlenecks are processes that limit throughput. Constraints are those points in the process where "flow thins to narrow streams". A particular process within a manufacturing or repair facility is analogous to a funnel where the mouth of the funnel is a non-constraint resource and the funnel's spout is a bottleneck or constraint resource (assuming a constant rate of flow through the funnel's spout). The water level would be the facility's work-in-process (WIP) inventory. If water or WIP enters the funnel (process) at a rate consistent with the size of the funnels spout (bottleneck resource capacity), then the water (WIP) would flow through without difficulty. (Fawcett and Pearson, 1991)

Because bottleneck resources limit a plant's production rate to their own capacity, the excess capacity of a non-constraining resource cannot be used to contribute to throughput. Additionally, the actual cost of a bottleneck is the total expense of the system divided by the time the

bottleneck produces. So the cost of an idle bottleneck per hour is actually the cost of the entire system per hour. (Goldratt and Cox, 1992)

The funnel analogy can also be used in explaining how WIP can lead to decreased turn-around-time (TAT) or lead time through the system. The higher the water level in the funnel the longer it takes for all the water to exit the spout (again, assuming constant flow through the spout). Similarly, the more WIP within a particular process at a facility, the greater the length of time an individual component takes to complete the process.

B. FIVE FOCUSING STEPS

Someone once said, "Good judgement is a result of experience and experience is gained from bad judgements." (Fox, 1984) If good judgement could be developed into a set of principles and then systematically applied, one might end up with something akin to Goldratt's "Five Steps of Focussing" (Goldratt and Cox, 1992) for guiding firms through a process of continuous improvement. The "Five Focusing Steps" are a direct logical deduction from the choice of throughput as the number one measurement (Goldratt, 1990a).

The five steps:

1. **IDENTIFY** the system constraint(s),
2. Decide how to **EXPLOIT** the constraint(s),
3. **SUBORDINATE** everything else to the above decision,

4. **ELEVATE** the system constraint(s), and

5. If in the previous steps, a constraint has been broken, go back to step 1. Repeat the steps. **WARNING!!!!** Do not let **"inertia"** become the constraint.

With this managerial framework, a real process of continuous improvement can be applied to any process but, of course, the process we should be most interested in is that of making money. All the steps are critical but without Step 5, there would be no continuous improvement.

1. Step 1, IDENTIFY the System's Constraint(s)

The initial step is to identify the firms constraint resources. "In the long run, every function - marketing, sales, distribution, production, materials, engineering or finance - every one of them, on its own, can block the throughput channel." (Goldratt, 1990b) From the limited research available in this area it appears that there are three basic methods for finding Goldratt's Herbie:[3]

1. Data Collection Method
2. Plant Type Method
3. Manual Method

[3] A fictional character synonymous to a constraint resource discussed in Goldratt's publications.

a. Data Collection Method

The basic idea behind the Data Collection Method is to use the company's existing management information system to find indications of demand exceeding a resource's capacity. A similar method is also called a "Capacity Resource Profile" by Chase and Aquilano.

In general however, a constrained resource may be said to exist if market demand is equal to or greater than the resource capacity. In the data collection method total market demand is calculated and compared to the capacity each resource has available for filling the particular demand. Current WIP is taken into account in determining resource capacity. To determine constraints at any given time would be highly dependent on data accuracy and ease of data manipulation, given a particular shop floor data collection system.(Chase and Aquilano, 1989)

b. Plant Type Method

This identification process varies depending on the type of operations employed and the products manufactured in a facility. The three basic plant varieties include the converging A-Plant, the diverging V-Plant and the manufacture-to-forecast, assemble-to-order T-Plant. Plants that possess attributes of more than one of the three basic varieties are called combination plants. The various types of plants are illustrated in Figure 2-1 (Fawcett & Pearson, 1991).

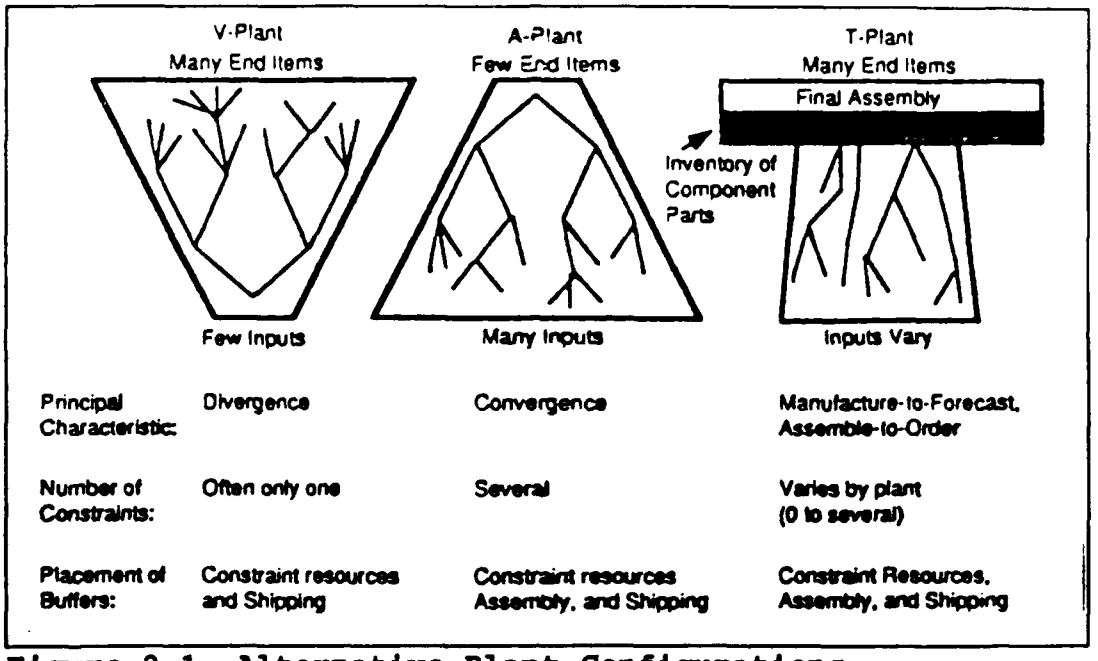


Figure 2-1. Alternative Plant Configurations.

- A-Plant - characterized by a large number of raw materials or component parts that are transformed into a small number of end items.
- V-Plant - Typically produces many end items from a relatively small number of raw materials or component parts.
- T-Plant - characterized by a large number of raw materials transformed into a large number of end items.

Although the Naval Aviation Depot environment may have characteristics of all types they most closely resemble the A-Plant. Within an A-plant a great many subcomponents, bit and piece parts and raw materials are used to repair, modify or overhaul a smaller number of aircraft, engines, components and support equipment. Chase and Aquilano list many characteristic problems associated with an A-Plant

including low equipment utilization, high unplanned overtime, parts shortages, lack of control over the repair process and, possibly indicative of a problem , the same machine being used several times on the same part during processing.

The key to identifying constraint resources in the A-Plant is to look at late or missing parts and follow the routing of these parts backwards until they converge at a common resource. Long inventory queues are also indicative of a constraint resource. Due to missing parts or changing priorities, workstations in the A-Plant tend to be set up and broken down more frequently. (Fawcett and Pearson, 1991) Machines that have multiple uses and therefore multiple setups are possible bottlenecks. A singular, highly skilled individual can also become a constrained resource. If that individual is sick or unavailable then WIP would stack up. People that are trained to only do a certain process and are overloaded with work are bottlenecks. Bottlenecks in A-Plant are also prevalent where multiple subassemblies are joined together to form the next higher assembly (TQM Division, 1990).

c. Manual Method

The manual method of identifying constrained resources is by far the cheapest, quickest and, since it involves workers on the shop floor, it will also encourage more proposals for methods to reduce the bottlenecks impact

(TQM Division, 1990). In order to determine where the constraints are located this method relies on the experience of the workforce, from managers to production controllers to artisans on the floor. Bottleneck resources are identified through visual inspection of the plant to determine where the greatest levels of WIP are located. Managers will probably have a good idea of where they could use more capacity. Production controllers should be queried as to parts shortages. The parts most frequently in short supply are probably the ones that pass through a bottleneck (Goldratt and Cox, 1992). Areas to look at include:

- specialized machines requiring lengthy setup;
- highly skilled personnel;
- resources requiring frequent overtime;
- machines requiring a great deal of maintenance;
- machines or processes that run jobs in batches.

Lastly, for all these methods, once the constraints have been located they should be prioritized according to their impact on the goal. (Goldratt, 1990b)

2. Step 2, Decide how to EXPLOIT/UTILIZE the System's Constraint(s)

The basic idea underlying attempts to maximize throughput is to increase the capacity of the bottleneck resource by either making better use of existing resources (exploiting the constraint) or by acquiring additional

capacity through capital investment (elevating the constraint) (Fawcett and Pearson, 1991). To exploit the constraint is to determine how to maximize the performance of the system given the constraint(s) (Gardiner and Blackstone, 1991). The constraints should always be exploited according to the organizational goal. Just because a bottleneck is always working, doesn't mean that the bottleneck is necessarily exploited. It should work on products that are the most profitable and only on those which are going to be sold soon (Schragenheim and Ronen, 1991). Exploiting the constraint therefore is not the same as maximizing the utilization of the constraint (Trietsch, 1992c). Goldratt and other authors don't make the distinction between exploitation and utilization, so in this paper we will use the terms interchangeably. Goldratt provides a few ideas for exploiting or utilizing the constraint such as ensuring the bottleneck's time is not wasted by sitting idle during a lunch break. Another waste is for the bottleneck to be processing defective parts or parts which tend to become defective later due to poor process control. As mentioned, building inventory now that won't be sold until some unknown future date is wasting the bottleneck's time. Also, to ensure the best utilization of constraint resources, an evaluation of the product mix should be performed. A company might discover that it should abandon or reduce production of a given product because the company's limited resources can be better utilized by focusing

on those products that provide the largest profit per constraint resource hour. (Goldratt, 1990a) Lastly, Goldratt asks, "Do all the parts presently being processed by the bottleneck need to be processed by the bottleneck?" Is it merely unnecessary company policy which says so? If the parts don't need to be processed through the bottleneck then shift the processing to nonconstraint resources. A corollary is to determine if the plant owns additional machines which perform the same process as the bottleneck and then offload to those machines. (Goldratt and Cox, 1992) Fawcett and Pearson mention other ideas such as training bottleneck operators to be more efficient, using setup engineering to simplify setup methods and improving preventive maintenance to reduce bottleneck downtime.

a. Drum

Another way to view the exploitation of the system constraint is through the analogy of a "drum" (Goldratt and Fox, 1986). The drum is seen as the constraint resource and sets the beat or production schedule for the rest of the facility (Fawcett and Pearson, 1991). The rate of the drum beat is the output that is expected from the bottleneck resource.

A further implication of constraint exploitation is the need to schedule the constraint. Since a constraint resource controls the throughput of the facility it will be

the focal point of scheduling efforts. All scheduling or exploitation of the bottleneck will, in turn, dictate the beat or rate at which other resources operate including material release into the plant, nonconstraint workcenters, final assembly and shipment. The drum dictates the flow of product through the plant and whoever performs scheduling must not accept any more requirements beyond those which can be processed through the bottleneck during a particular time period. (Schragenheim and Ronen, 1991)

b. Buffer

A method for increasing the chances of fully exploiting the bottleneck and to decrease the risk that the bottleneck or drum will be exposed to disruptions is to place a time buffer directly in front of the bottleneck (Schragenheim and Ronen, 1991). A time buffer is safety stock expressed in time units vice quantity that is used to protect the bottleneck from upstream disruptions. The buffer is expressed in time because the facilities rate of flow is to be managed as opposed to its local capacities. The time buffer amount is actually authority to produce until the buffer is filled. If plant capacity can't keep up with market demand then the buffer will never fill up. Likewise, a full time buffer would signal for the induction rate to be inhibited. A time buffer is a tool needed to manage the statistical variation of the dependent repair or manufacturing

process.(Spencer, 1991) Variations might result from machine breakdowns, absenteeism, setup time fluctuations, unreliable vendors, scrap or just unavailability of a certain downstream resource due to use on other jobs (Schragenheim and Ronen, 1991). For a two-day time buffer, parts or raw materials would be released into the system so that they would arrive two days before they are actually required by the constraint.

Generally, buffers are placed in front of the assembly points and shipping areas as well as the constraint resource (Fawcett and Pearson, 1991). Assembly buffers protect against disruptions which occur in the acquisition and manufacture of parts processed through nonconstraint resources. Parts coming through constraint resources are already protected, so to ensure throughput is protected, all that is additionally needed is a time buffer placed in front of the assembly area (Spencer, 1991). A buffer is also placed at the end of the production process to assure high levels of due date performance for all products that contain no parts processed through a constraint resource. (Fawcett and Pearson, 1991)

Buffer management begins by comparing planned with actual content of the buffer to identify parts or materials that should have arrived if the system were functioning without variation. The source of the disruption is located by tracing the missing parts back through the system. (Fawcett and Pearson, 1991) Schragenheim and Ronen list the benefits

of buffer management:

- serves as an alarm system that spots serious and urgent problems which threaten to disrupt the plan and cause damage;
- provides control on lead-time;
- indicates the weak areas, thus prioritizing the necessary improvements in the shop floor.

Because the time buffer helps to exploit the constraint resource and also to decrease the chance of downstream disruptions affecting the bottleneck, it leads naturally into the next step.

3. Step 3, SUBORDINATE everything else to the above decision

The purpose of this step is to guarantee the exploitation remains unimpaired (Schragenheim and Ronen, 1991), by ensuring that the nonconstraints do not supply any more WIP inventory than can be processed effectively by the bottleneck. (Goldratt, 1990b) In order to ensure that inventory does not exceed the authorized time buffer interval, the rate at which material is released into the plant must be linked to the constraint resource production rate (Goldratt and Fox, 1986). Unless there is already a lot of excess inventory on the floor there is not much point in scheduling various *nonconstraint resources*. It's enough to firmly control the material release and tell everyone to work on material in the sequence it arrives or at most, if material arrives early by mistake or fluctuation, tell workcenters not

to go into work before the date required to meet buffer needs. (Goldratt, 1990a) This general material releasing technique is also used to schedule backwards from the shipping and assembly buffers. The link between the buffers and their gating or first operation is called a "rope" (Goldratt and Fox, 1986).

a. Rope

Ropes ensure that nonconstraint resources will be subordinate to the drum, or in other words, only material scheduled by the drum will be available for processing by nonconstraints previous to the drum. Resources following the constraint will obviously be loaded only as fast as the drum can beat. The subordination rule is critical to the protection of the drum (constraint) in that it ensures that there will be excess capacity within the nonconstraints available to catch up to the needs of the constraint in case of disruptions downstream. (Schragenheim and Ronen, 1991) Chase and Aquilano mention that the rope need not be as formal as a written schedule, and may take the form of daily discussions.

b. Drum-Buffer-Rope (DBR)

The DBR technique combines each of the named concepts in a synchronized fashion to ensure smooth scheduling of parts and material flow throughout a facility. It is a particularly applicable scheduling system to use in

conjunction with TOC. (Goldratt and Fox, 1986)

4. Step 4, ELEVATE the system's constraint(s)

"Whatever the constraints are, there must be a way to reduce their limiting impact. If we continue to elevate a constraint then there must come a time when we break it. This thing that we have elevated will no longer be limiting the system." (Goldratt, 1990b) What will then limit the system will be the previous second most capacity constrained resource. Elevating the constraint could involve capital investment or policy changes or perhaps a marketing approach to increasing demand for product. In elevating the constraint one must anticipate the consequences. For example:

> In a complex plant the purchase of million-dollar pieces of equipment can alter the flow dramatically, but to what end? Simulations can be done beforehand to discover what the impact will really be. For instance, buying an additional machine that will double throughput at a bottleneck may create a bottleneck someplace else. If the new bottleneck is located earlier than the old one, the new resource would never be utilized to full capacity. If the new bottleneck occurs after the old one, some of the added throughput of the new machine will be useless (Lundrigan, 1986)

The above example is informative, however the authors use of the term "throughput" is not quite accurate. Throughput of the system can be increased, and the bottleneck does limit throughput, but there is no such thing as throughput at a bottleneck unless the bottleneck is revenue generation. Throughput is the rate at which the system generates money through sales. The example nonetheless does

point out possible ramifications of throwing money or capital at a problem indiscriminately. Any approach to elevating the constraint could be wrong if all internal and or external constraints have not been properly identified. It is the process of identifying and eliminating physical, policy, marketing interface, political, etc., constraints that determines what the organization should be doing over the next several years. This is what strategic planning is all about - determination of constraints and a focused approach on actions required that will lead the organization to an elevated status relative to the status-quo. (Weston, 1991)

5. **Step 5, If in the previous steps a constraint has been broken, go back to step 1. WARNING!!!! Do not allow INERTIA to cause a system's constraint**

Each successful eradication of a constraint is the birth of another. The key is ongoing improvement. Removal of one constraint will signal the beginning of the "Five Focussing Steps" in searching for another.

The meaning of step 5 is fairly self evident. However, the term "inertia" needs to be clarified. Inertia could be restated as the psychology of the organization. The organization itself has its own psychology which is not equivalent to the psychology of the individuals that make it up (Goldratt, 1990b). Things are usually done a certain way in organizations and there is some comfort in feeling

knowledgeable about standard operating procedures. The following line of reasoning is taken from Goldratt's book "What is this thing called TOC" and explains how inertia can happen on a more personal level:

1. In order for ongoing improvement to occur change must be the norm and not the exception;
2. Any improvement is a change;
3. Any change could be a perceived threat to someone;
4. Any threat gives rise to emotional resistance.

C. SUMMARY

Edmund Burke, British author and statesman wrote in 1790 in his "Reflections on the Revolution in France", "A state without the means of change is without the means of its conservation." The "Theory of Constraints" provides a means for not only change but ongoing improvement, and therefore the ability to make money now and in the future. Focused ongoing process improvement needs to be the inertia of our organizations. But, in "The Race" Goldratt says part of TOC is that, "... we must think even harder to find even better processes."

III. NADEP ORGANIZATION

The focus of this chapter will be on the organization of the Naval Aviation Depot (NADEP), North Island (NI), California. NADEP NI's functional and program management structural composition will be discussed. The responsibilities of upper management through floor level shop functions will be described in the processing of components. The component flow will be analyzed in later chapters. Due to the breadth and depth of the organization, descriptions will be brief and only the main functional and program entities will be discussed.

The six depots have evolved, in some respects, independently and so the descriptions contained herein are not necessarily indicative of what will be found at other NADEPs.

A. NADEP CORPORATION

The six Naval Aviation Depots that comprise the NADEP Corporation are the Naval Air Systems Command's (NAVAIR) principal in-service logistic support activities. The NADEPs fulfill Program Management and Cognizant Field Activity (CFA) responsibilities in addition to providing industrial maintenance and engineering functions in support of the operating fleet. The NADEP Corporation is presently in the second year of a five-year plan to streamline its production

and management efforts, to eliminate redundancies and to reduce overhead costs.

The Corporation has been organized around two hub depots; one each on the east and west coasts. Each hub organization is composed of three NADEPS and a supporting Business Operating Center (BOC). The east coast hub BOC is located at NADEP Norfolk, Virginia and performs administrative support functions for the NADEPs at Jacksonville, Florida and Cherry Point, North Carolina. NADEP North Island, San Diego, California serves as the west coast corporate BOC. North Island is administratively tied to the NADEPS at Alameda, California and Pensacola, Florida. (Strategic Planning Branch, 1992)

B. BACKGROUND

Generally, NADEP NI has been organized as a matrix organization. Functional managers can be thought of as being imposed across the horizontal axis while Program Management Team responsibilities cut through the organization across the vertical axis. Each functional manager provides services (manpower) to the program managers and, in return, receives funding through the program manager. Operations directorate restructuring was still occurring in June of 1992 and by the completion of this thesis there had been no formal command organization chart published. The following chart shows the

major functional areas of the command and the major program management areas.

NADEP ORGANIZATION CHART

	DIVISION/FUNCTIONAL MANAGERS								
		Prod'n Control	Prod'n Plan'g	Mat'l Supt	Fac Eng	Prod	Eng	Qual Assur	Bus Off
P M T O ' S	Components								
	E-2/C-2								
	F/A-18								
	Field Serv								
	Engines								
	Mfg'g								
	Software								

Captain C. N. Sapp, USN, Commanding Officer of NADEP NI, said, as introduction to the command's "Commodity Realignment Master Plan":

> In October, 1990, NADEP North Island initiated a realignment of it's operations to improve performance, productivity, quality and reduce operating costs. The new business base that resulted increased our ability to compete for workload in the highly competitive and austere environment of the future. Our realignment divided NADEP NI's operations into commodity groups, which in turn, are composed of product lines. We now have a plan for each product that identifies, manages, schedules and executes the activities needed by each of our customers. These plans are living documents and will be updated to keep

pace with, and adapt to, the requirements of a dynamic and increasingly competitive market place. (C.N.Sapp, 1991)

The results of the reorganization will be discussed in the rest of this chapter. First the functional components and then the program or commodity organizational elements will be described. Past and present structures have been commingled so only a description of the evolved organization can be detailed.

C. NADEP FUNCTIONAL ORGANIZATION

This section provides a brief explanation of the functional organization main players and their responsibilities.

1. Commanding Officer (CO)

The Commanding Officer (CO) of NADEP NI is charged by Naval Air Systems Command (NAVAIRSYSCOM) to direct the command's operations.

2. Executive Officer (XO)

The Executive Officer (XO) assists the CO through supervision of all command functions. The XO also performs duties as the Director of Programs which will be reviewed later in this chapter.

3. Executive Steering Committee (ESC)

NADEP NI is guided by an Executive Steering Committee (ESC). The ESC establishes command policy, sets standards for

accountability and oversees NADEP operations . It prepares and manages the accomplishment of the command's strategic business plan and outlines the key areas of focus along with the goals and objectives that the command will accomplish each year of the planning horizon. It accomplishes this through the organization of specialized subcommittees which set goals, approve plans and direct action in correcting environmental situations which affect the depot. The ESC establishes and maintains a Total Quality Program and process improvement goals which are integrated into daily operating procedures. (Bransford, 1992)

4. Directors

Directly charged with enacting ESC policy are the NADEP Directors; the Directors of Programs, Quality, Operations, Product Support, Navy Primary Standards Lab and the Business Office and Business Operating Center (BOC). Directors manage functional operations (with the exception of the Director of Programs) through monitoring execution and directing corrective action whenever deviation exceeds control limits. They act as the single command representative on corporate issues affecting their respective function. (Bransford, 1992)

5. Functional Managers

Following the Directors in the chain of command are the Division Directors and Branch Managers (also known as

Functional Managers). A primary responsibility of each functional manager is the estimating of the resources necessary to produce scheduled requirements. They then negotiate the funding for the needed resources with the program manager (who allocates funding). Finally, they ensure the resources are in place when the particular depot process demands them. (NADEP NI, 1991)

6. Consolidated Control Centers (CCC) / Material Control Centers (MCC)

Immediately under the Division and Branch Managers and Supervisors in the functional organization are individual members of the Consolidated Control Centers (CCC) and Material Control Centers (MCC). CCC's and MCC's are designed to combine human resources from the functional entities into centralized locations throughout the depot. The prime expectation is to bring individuals together, combining talents and expertise, to allow effective management and execution of the day-to-day operations of a specific commodity. For example, within the Components commodity section there is a CCC which is responsible for managing the operations of a specific group of work centers which process various types of hydraulic components. Other commodities could include F/A-18 engines or E2-C rotodomes. Other expectations of the CCC and MCC are that members will work toward the same goals, quality awareness and continuous

improvement will ensue, and immediate problem resolution and opportunity growth will occur. (Lounsberry, 1991)

All members of the CCC share broad responsibility for total team success and specific functional responsibility for their area of expertise. Individual shop foremen are participants in CCC functions but are physically located adjacent to their applicable shop. The following functions are physically located in the CCC adjacent to the designated shop areas:

- Planner and Estimator(s)
- Production Controller(s)
- Material Expeditor(s)
- Quality Assurance Specialist
- Equipment Specialist(s)
- Industrial Engineering Technician(s)

a. Planner and Estimator (P&E)

The Planner and Estimator (P/E) is responsible for planning and scheduling workload to be inducted into production shops under his jurisdiction. In order to satisfy customer[4] needs, the P/E takes whatever steps are necessary to respond to all production schedule shortfalls.

Planning involves an analysis of the manpower, capabilities, capacities, support material, tooling technical data, facilities, priorities, time and cost allocations required to support his or her projects and programs. The P&E assigns work priorities to Production Control and reviews

[4] The P/E customers are ASO and NADEP NI.

manhours/material expenditures to ensure the NADEP is competitive with Alternate Designated Overhaul Points. (NADEP NI, Unk) (King, 1992)

b. Production Controller (PC)

Assigned to the CCC or MCC Team from the Production Planning and Control Department, the Production Controller (PC) plans, coordinates and controls the assigned product workload at the shop level. The incumbent schedules and, via Material Expeditors, releases work into production shops after considering workload status, priority and availability of manpower, equipment and material. The PC resolves production delays and works closely with production and support activities and the applicable Program Management Team Office (PMTO). (PMTO's will be described in full later in this chapter) PC's maintain accumulation and/or kitting areas for receipt, storage, accountability and issue of Ready-For-Use (RFU) parts, subassemblies and assemblies. (NADEP NI, Unk) (King, 1992)

c. Quality Assurance Specialist (QAS)

The Quality Assurance Specialist (QAS) ensures the implementation and administration of the Quality Program within the CCC and MCC. He or she is under the Quality and Reliability Assurance Department's functional line of supervision. The QAS establishes product and process quality requirements and determines quality characteristics on

aircraft, aircraft systems, engines, components and support equipment. The incumbent advises management and other personnel on the quality and reliability of products, processes, and systems and makes problem solving recommendations. (King, 1992) The QAS utilizes Statistical Process Control (SPC) data, trend analysis, reliability studies and process improvement data to provide feedback and measurements of quality.(NADEP NI, Unk)

d. Equipment Specialist (ES)

The ES is primarily responsible for providing the logistical elements necessary for the management of material, consumables and repairables required to support all workload identified by the PMTO and CCC. He or she monitors material through the supply system or commercial contractors and vendors on current government contract to ensure timely availability of that material. The incumbent strives to minimize material and delivery costs and ensures the PMTO, CCC and appropriate managers are aware of status.(NADEP NI, Unk)

e. Industrial Engineering Technician (IET)

The incumbent is primarily responsible for reviewing standard depot level maintenance specifications and other technical data and directives for work content; development and maintenance of Master Data Records for all assigned workload; development and maintenance of operation

standards for all assigned workload; providing on-site monitoring for appropriate work operation processes, sequencing and routing; identifying improvements to management in areas of improved work methods and utilization of labor saving devices; and overseeing and coordinating special product studies initiated by the program manager. Functional direction and administration is achieved through the IET Supervisor.(King, 1992)

7. Shop Level

The particular shops within NADEP NI to be discussed below have been limited to those involved in repair or overhaul of components which are also routed through and must be tested on the Servocylinder Test Station (STS); shop 93302. Those include:

a. Shops within the Engines/ Hydraulic and Component Division, Code 93000:

- 93302: *Servocylinder Test Area/ Pumps/Motors/Drag Braces/ Dampers/ Control Valves/Aileron Actuators;*
- 93303: *Constant Speed Drives/ Flight Controls/Hydraulic Units/Pumps and Test;*

b. Shops within the Components and Metal Division Manufacturing Production Management Center, Code 97000:

- 97103: *Spring and Wire Support/ Accessories Support Shop;*
- 97107: *Component Refurbishment Machine Shop;*
- 97206: *Sheetmetal Manufacturing and Mobile Facilities Shop;*
- 97401: *Metal Spray, Shot Peening and Sandblast Shop;*

- 97402: *Processing/ Cleaning and Paint Shop;*
- 97403: *Electroplating and Heat treat Shop;*
- 97405: *Nondestructive Inspection Shop;*

This completes the functional entities with which this thesis will refer to in follow-on chapters.

D. NADEP PROGRAM MANAGEMENT ORGANIZATION

This section provides a brief explanation of the NADEP Program or Commodity Management philosophy and primary responsibilities of the main players. As an example, the Component Program Management Team Office (PMTO) personnel responsibilities will be discussed to further clarify the PMTO relationship with the repair processes.

1. Director of Programs

The NADEP's Executive Officer is also the Director of Programs and, as such, all Program Managers report directly to him. This, in effect, flattens the previously vertical organization allowing for rapid communications from top management to every integral part of the NADEP and back again. Communication is facilitated via process or program management in addition to the functional chains of command described above.

The Director of Programs allocates all program funds and reviews and approves all changes in the NADEP workload which affect the current or planned distribution of resources across all programs (NADEP NI, 1992). This impacts directly

on both the functional and commodity management echelons. It allows for rapid dissemination of information throughout the organization and therefore flexibility in meeting shifting priorities.

2. Program Managers

The concept of program management came in large part due to a desire to facilitate communications throughout the Depot. This, in turn, would lead to more efficiency, less complexity in operations and therefore better service to the fleet. Underlying this effort was also a Navy wide initiative toward continuous improvement and quality management. The Defense Management Report of 1989 created an urgency for continuous improvement, for reducing overhead costs and eliminating redundant operations within the Navy. Additionally during this period the Navy realized a need to become more customer oriented, quality-conscious and streamlined; rapidly adaptable to the changing security, technological and fiscal realities of a dynamic world. (Strategic Planning Branch, 1992)

Toward this end the North Island Depot Realignment Team developed an overall strategy that aligned product and service structure to provide effective and efficient utilization of "personnel, machines, materials, methods and money". In support of this effort, commodity or program

management teams were structured to exploit the NADEP's distinct competencies. (NADEP NI, 1991)

a. Components/SE/Calibration Program Manager

The Components Program Manager directs and coordinates the activities of his respective PMTO. He negotiates, plans, manages and allocates funding and manhours for all components, SE and calibration workload processed at the NADEP. The Components Program Manager and PMTO personnel represent the command directly to ASO, NAVAIR, Naval Aviation Depot Operation Center (NADOC), Commander Naval Sea Systems Command (NAVSEA) and inter-service customers. (NADEP NI, 1991)

(1) Component PMTO members include:

ASO F/E Program Manager - Ensures proper management of NADEP's proposed and funded component workload. This includes Level Scheduled Repair, B08 PROBE, Container Repair (6K), Consumables Repair (1R) and Armament (4Z). Monitors financial expenditures, material, manhours expended versus workload standards and directs corrective action as necessary. Prepares status reports and graphs. Negotiates specific work requested by DOD agencies. (Vest, 1992), (NADEP NI, 1991)

ASO F/E Program Coordinator - Working for the ASO F/E Program Manager, the coordinator develops product completion schedules and maintains ongoing cognizance and customer liaison for assigned products consistent with customer requirements, available funding and plant production and support capacity. The incumbent investigates production shortfalls to identify causes and develop corrective action. (Endrizzi, 1992), (NADEP NI, 1991)

RSI V-Pool/Installed Components Program Coordinator The Retail Stock Inventory (RSI) is a pool of components made available when the anticipated component Turn-Around-Time (TAT) is greater than the major end item's TAT. The coordinator maintains an awareness of the potential workload for assigned items through ongoing contact with customers and develops product completion schedules for assigned products consistent with customer requirements, available

funding and plant production and support capacity.(Fancy, 1992)

DMISA Program Coordinator and MICO - The Depot Maintenance Interservice Support Agreement Coordinator and the Maintenance Intra/Interservice Coordinator work jointly within the Components PMTO in developing and directing a comprehensive depot maintenance intra/interservicing program. The incumbents recommend policy for all DMISA support matters and coordinate the development of capability and cost response packages.(Kiklis, 1992), (Vest, 1992), (NADEP NI, 1991)

Other Support Program Coordinator - Coordinates the requirements of the Components Customer Service and Foreign Military Sales (FMS) Programs along with Special Projects. Anticipates production shortfalls by monitoring operations and advises customers of the status of production commitments.(Stoker, 1992), (NADEP NI, 1991)

Support Equipment Program Coordinator - Maintains overall cognizance of the status of production relative to negotiated Support Equipment product completion schedules. Investigates production shortfalls or potential shortfalls to identify causes and develop corrective actions. Develops product completion schedules. (Vest, 1992)

Avionics Calibration Program Coordinator - Coordinates In House, On Site, Fleet and Type 1 Calibration. Advises customers of the status of production commitments and responds to customer inquiries concerning assigned items. Develops product completion schedules for assigned products consistent with customer requirements, available funding and plant production and support capacity.(Vest, 1992)

b. E-2/C-2 Program Manager

The manager of the E-2/C-2 PMTO negotiates funds, plans and manages all E-2C Hawkeye Early Warning aircraft and C-2A(R) Greyhound aircraft workload processed at the NADEP. The PMTO represents the command through direct liaison and support to the E-2/C-2 Program Manager Air (PMA), Assistant

Program Manager Logistics (APML), Type Commander (TYCOM) Class Desk and operational Wings/Squadrons. (NADEP NI, 1992)

c. F/A-18 Program Manager

With respect to the F/A-18 Program, the F/A-18 Program Manager performs the same functions as the E-2/C-2 Program manager.

d. Manufacturing Program Manager

The incumbent negotiates, plans, manages and allocates funding for all manufacturing workload processed at the NADEP (including the manufacture of items to support in-house NADEP programs). Manufacturing includes numerical control machining, sheetmetal fabrication, composites, electronic component assembly, carpentry, etc.. The manager also develops and uses external manufacturing sources that provide cost effective alternatives to internal NADEP manufacturing, e.g. Public Works Center (PWC). The manager represents the command through direct liaison and support to ASO, NAVAIR and other external customers. (NADEP NI, 1992)

e. Engines Program Manager

The incumbent negotiates, plans, manages and allocates all funds and manhours for all engine workload processed at the NADEP. The Engines Program Manager and PMTO represent the command through direct liaison and support to all external customers or administrative commands.(NADEP NI, 1992)

f. Field Service/VRT Program Manager

The incumbent directs and coordinates the activities of the Field Service/Voyage Repair Program Management Team. Depot level repair is provided to shore and underway fleet aviation commands and ship catapult and arresting gear on routine and emergency basis. The manager allocates funding and manhours and represents the command to external activities. (NADEP NI, 1992)

g. Software Program Manager

The program manager plans and manages the development and maintenance of all Airborne/Automatic Test Equipment (ATE)/Aviation Trainer/Maintenance Trainer Software supported by the NADEP. The incumbent manages and allocates funding for the equipment and software and represents the command to NAVAIR, other software support activities and operational wings. (NADEP NI, 1992)

E. SUMMARY

This chapter has described NADEP NI's organization and in doing so, something of its managerial philosophy. The main functional and program organizational players have been identified AND their interaction within the depot maintenance environment are described. This chapter provides the basis for comprehending specific material flows and production actions that will be discussed in later chapters.

IV. PRODUCTION PLANNING AND SCHEDULING

In this chapter we will look at how the Component PMTO and related shops currently plan and schedule their workload. We will describe the process and explain the roles of the key players involved.

A. CAPACITY PLANNING

Matching the planned and forecasted workload to each shop's capacity is the responsibility of both the Planner/Estimator (P/E) and the Program Management Team Office (PMTO). In the Component Section the P/Es, with input from the various CCC members, estimate the available capacity in man-hours of each shop for the next quarter. The P/E takes the total number of projected man-hours available and subtracts the projected carry-over WIP man-hours to derive the shop's capacity for the next quarter. P/Es have attempted to use other measures of capacity for workload planning and scheduling with mixed results (Ganough, 1992). At least for the foreseeable future, P/Es will only use man-hours available to measure capacity.

Once the P/E derives an estimate of capacity available, the estimate is forwarded to the P/E representative in the PMTO. If forecasted workload exceeds capacity, the program manager has several options available. He can: (1) negotiate

with his customers for less work; (2) negotiate for longer lead times; or (3) request assets from other activities in the depot to meet the extra workload. In the case where capacity exceeds workload, he can negotiate for more workload with his customers or temporarily shift some of his assets to other sections in the depot.

B. SOURCES OF WORK

The Component Section has three major sources of work. They are: (1) installed components from aircraft being overhauled at North Island; (2) ASO managed Aviation Depot Level Repairables (AVDLR); and (3) components from other services within DOD under the Depot Maintenance Interservice Agreement (DMISA) program. The majority of the workload at present is ASO AVDLRs. We reviewed the past eight quarters of workload history and saw that AVDLRs comprised 60 to 80% of the section's workload. The percentage of AVDLR workload varied from shop to shop but, in every case, AVDLRs represented the majority of the work. Installed components and DMISA items represented the remaining workload. The workload percentage of these items also varied between shops. Some shops had a higher percentage of installed components while others had a higher percentage of DMISA items.

The Component Section receives AVDLRs from ASO under the level schedule program and through the Uniform Inventory Control Program (UICP) repairables management software

program, commonly referred to as B08. Level scheduling is a relatively new program used by ASO inventory Item Managers (IM) and maintenance managers to schedule repair of AVDLRs. It is an off-line manual process that the IM uses to ensure assets are available to meet fleet needs. Normally, only high impact items that significantly affect fleet readiness qualify for level scheduling (NAVSUP PUB 553). The idea behind level scheduling of AVDLRs is to feed the repair process at a steady rate in order to reduce lead times and eliminate variability in both the inventory and repair processes. (Moore, 1992)

In contrast, the Component Section also receives different jobs weekly from the UICP Repair Management Program B08. That process is called a "B08 PROBE" by the P/Es. The B08 software contains the computerized rules for scheduling the repair of unserviceable assets that are in the wholesale supply system (NAVSUP PUB 553). This software application compares assets to forecasted requirements and generates repair quantities necessary to meet those requirements. The time horizon in the requirements determination is the item's repair TAT time. ASO runs this "PROBE" weekly. Therefore, the Component Section may receive highly variable weekly work requests from ASO throughout the quarter. Urgency of Need levels are used to prioritize the work sent to the depots. The depot uses these priority designators when scheduling the jobs into the repair shops. There are four Urgency of Need levels with level 1 being the most critical and level 4 the least. For a more

detailed explanation of Urgency of Need levels see NAVSUP PUB 553, Chapter 3.

C. NEGOTIATION AND CANCELLATION PROCESSES

Prior to the start of a new quarter, the P/E receives repair requests from ASO for items managed under the level schedule program. The P/E looks at each repair shop he supports to ensure that the shop has the capacity and capability needed to do the work. He also checks on repair part availability for the items being repaired. Additionally, he identifies "extra" capacity that could be used to negotiate more work from ASO. He then develops an estimate of the amount and type of work his shops are able to perform. This estimate is reviewed by the CCCs, primarily for coordination, prior to submission to the Component's PMTO. The CCC review is also used as a means of gaining each player's support for the proposed amount of workload. The final estimate is then turned in and approved by the Component PMTO.

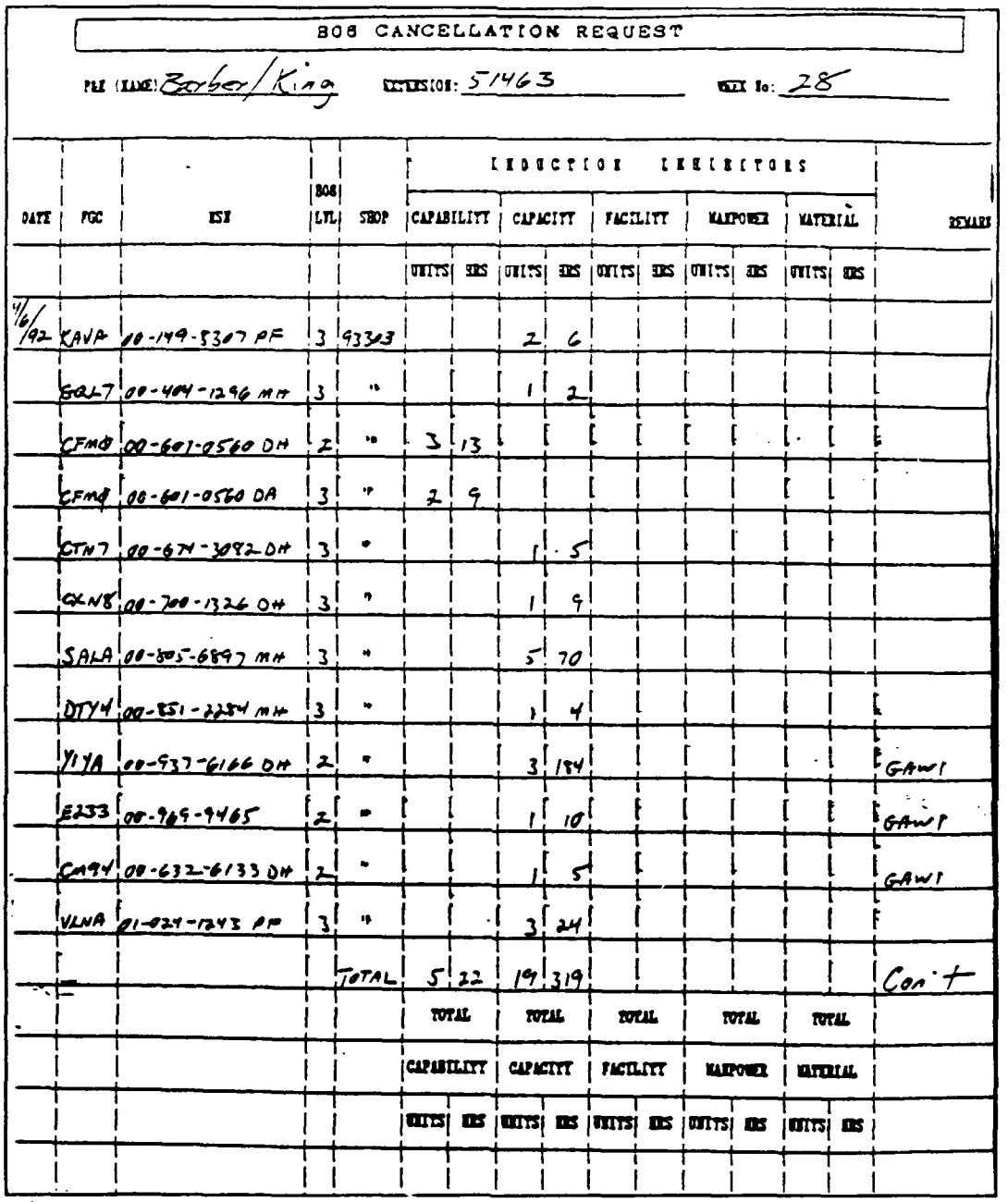
Based on the estimates submitted by the P/Es, the PMTO then goes to ASO to negotiate a final level-schedule workload for the next quarter. Repair quantities are then negotiated and agreed upon for the next quarter.

Throughout the quarter, the P/E will normally receive a weekly B08 PROBE from ASO for repair of AVDLRs supported by the section. When a P/E receives a PROBE, he must ensure the shop(s) that repair the AVDLRs have the capacity, capability

and repair parts available to do the work. He coordinates with the foreman to determine capacity available and current capabilities, and checks with the P/C and material specialist for repair parts availability. He can cancel B08 Urgency of Need Levels Three and Four requirements for lack of any one of the above pre-conditions. However, he cannot cancel Level One and Two requirements. In those cases, he informs the PMTO and ASO of the problems and awaits resolution at a higher level.

Figure 4-1 is an example of a cancellation request for a B08 PROBE with Urgency of Need Levels 2 and 3. This form contains five categories of constraints, but only the first two categories (capability and capacity) are used (King, 1992). Capability refers to whether the depot has the ability to do the work and capacity refers to whether the depot has adequate resources available.

In this example, the first requirement (NSN00-149-8307) from B08 was for 2 units in Shop 93303 and a total of 6 hours. There is no capacity left to do it and it was cancelled. The third requirement (NSN00-601-0560) from B08 was for 3 units totaling 13 hours in the same shop. The shop currently does not have the capability to repair that NSN so that requirement was cancelled. From this example, we can see that a total of 5 units requiring 22 hours of shop time was not able to be done because no capability existed for repairing the NSN. In addition, a total of 19 units consisting of 319 hours of shop time could not be done due to a lack of capacity.



B08 CANCELLATION REQUEST

FILE (LAST): Barber/King EXTENSION: 51463 WEEK No: 28

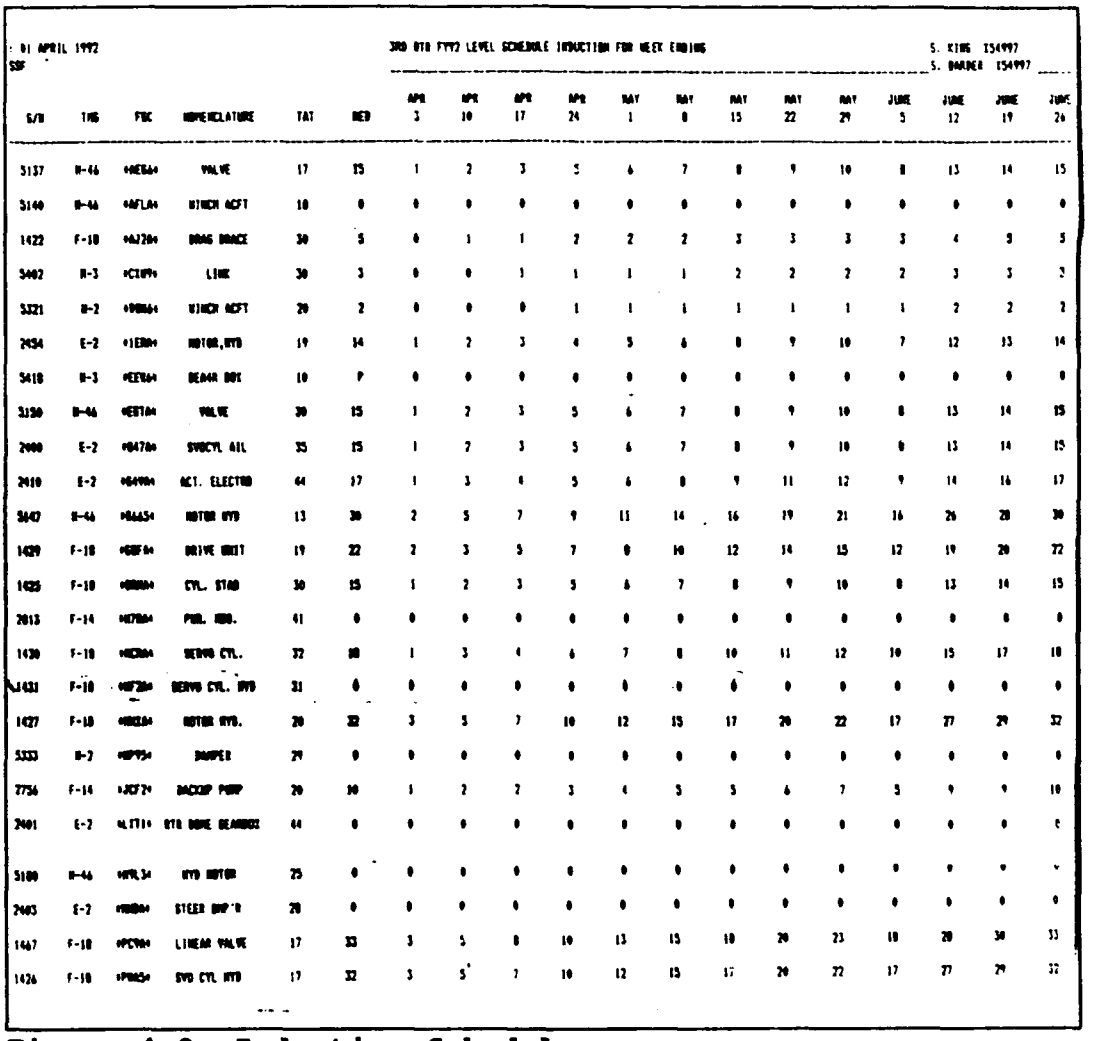
DATE	FGC	NSN	B08 LTL	SHOP	REDUCTION INDICATORS										REMARKS
					CAPABILITY		CAPACITY		FACILITY		MANPOWER		MATERIAL		
					UNITS	HRS	UNITS	HRS	UNITS	HRS	UNITS	HRS	UNITS	HRS	
11/6/92	KAVA	00-149-5307 PF	3	93303			2	6							
	GQL7	00-404-1296 MH	3	"			1	2							
	CFM8	00-601-0560 DH	2	"	3	13									
	CFM8	00-601-0560 DA	3	"	2	9									
	CTN7	00-674-3092 DH	3	"			1	5							
	CXN8	00-700-1326 DH	3	"			1	9							
	SALA	00-805-6897 MH	3	"			5	70							
	DTY4	00-851-2284 MH	3	"			1	4							
	YIYA	00-937-6166 DH	2	"			3	184							GAW1
	E233	00-969-9465	2	"			1	10							GAW1
	CA94	00-632-6133 DH	2	"			1	5							GAW1
	VLNA	01-029-1243 PF	3	"			3	24							
				TOTAL	5	22	19	319							Cont
					TOTAL		TOTAL		TOTAL		TOTAL		TOTAL		
					CAPABILITY		CAPACITY		FACILITY		MANPOWER		MATERIAL		
					UNITS	HRS	UNITS	HRS	UNITS	HRS	UNITS	HRS	UNITS	HRS	

Figure 4-1. Workload Inhibitor Worksheet For B08 Cancellations.

D. WORKLOAD SCHEDULING

Once the level-schedule repair quantities are finalized at the quarterly ASO Level-Schedule meeting, the P/E develops an

induction schedule for the shops. Figure 4-2 is an example of an induction schedule for the 3rd quarter, FY 92 for shop 93303. It shows the cumulative number of each type of component the shop should have inducted by the date shown in each week of the quarter in order to complete the required by the end of the quarter.



01 APRIL 1992 — 3RD QTR FY92 LEVEL SCHEDULE INDUCTION FOR WEEK ENDING — S. KING 154997, S. BARNER 154997

S/N	TMS	FSC	NOMENCLATURE	TAT	REQ	APR 3	APR 10	APR 17	APR 24	MAY 1	MAY 8	MAY 15	MAY 22	MAY 29	JUNE 5	JUNE 12	JUNE 19	JUNE 26
5137	H-46	4[illegible]	VALVE	17	15	1	2	3	5	6	7	8	9	10	8	13	14	15
5140	H-46	4AFLA4	HINGE ACFT	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1422	F-18	4AJ284	DRAG BRACE	30	5	0	1	1	2	2	2	3	3	3	3	4	5	5
5402	H-3	4C1894	LINK	30	3	0	0	1	1	1	1	2	2	2	2	3	3	3
5321	H-2	4[illegible]	HINGE ACFT	20	2	0	0	0	1	1	1	1	1	1	1	2	2	2
2454	E-2	4[illegible]	MOTOR,HYD	19	14	1	2	3	4	5	6	8	9	10	7	12	13	14
5418	H-3	4EE864	GEAR BOX	10	9	0	0	0	0	0	0	0	0	0	0	0	0	0
5130	H-46	4EE184	VALVE	30	15	1	2	3	5	6	7	8	9	10	8	13	14	15
2900	E-2	4[illegible]	SVDCYL AIL	35	15	1	2	3	5	6	7	8	9	10	8	13	14	15
2910	E-2	4[illegible]	ACT. ELECTRO	44	17	1	3	4	5	6	8	9	11	12	9	14	16	17
5447	H-46	4[illegible]	MOTOR HYD	13	30	2	5	7	9	11	14	16	19	21	16	26	28	30
1429	F-18	4[illegible]	DRIVE UNIT	19	22	2	3	5	7	9	10	12	14	15	12	19	20	22
1425	F-18	4[illegible]	CYL. STAB	30	15	1	2	3	5	6	7	8	9	10	8	13	14	15
2013	F-14	4[illegible]	PWR. MOD.	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1430	F-18	4[illegible]	SERVO CYL.	32	10	1	3	4	6	7	8	10	11	12	10	15	17	18
1431	F-18	4[illegible]	SERVO CYL. HYD	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1427	F-18	4[illegible]	MOTOR HYD.	20	32	3	5	7	10	12	15	17	20	22	17	27	29	32
5333	H-2	4[illegible]	DAMPER	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7756	F-14	4JCF2[illegible]	BACKUP PUMP	20	10	1	2	2	3	4	5	5	6	7	5	9	9	10
2401	E-2	4LTT1[illegible]	HYD DRIVE GEARBOX	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5100	H-46	4[illegible]	HYD MOTOR	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2403	E-2	4[illegible]	STEER BRK'R	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1447	F-18	4PC984	LINEAR VALVE	17	33	3	5	8	10	13	15	18	20	23	18	28	30	33
1426	F-18	4[illegible]	SVD CYL HYD	17	32	3	5	7	10	12	15	17	20	22	17	27	29	32

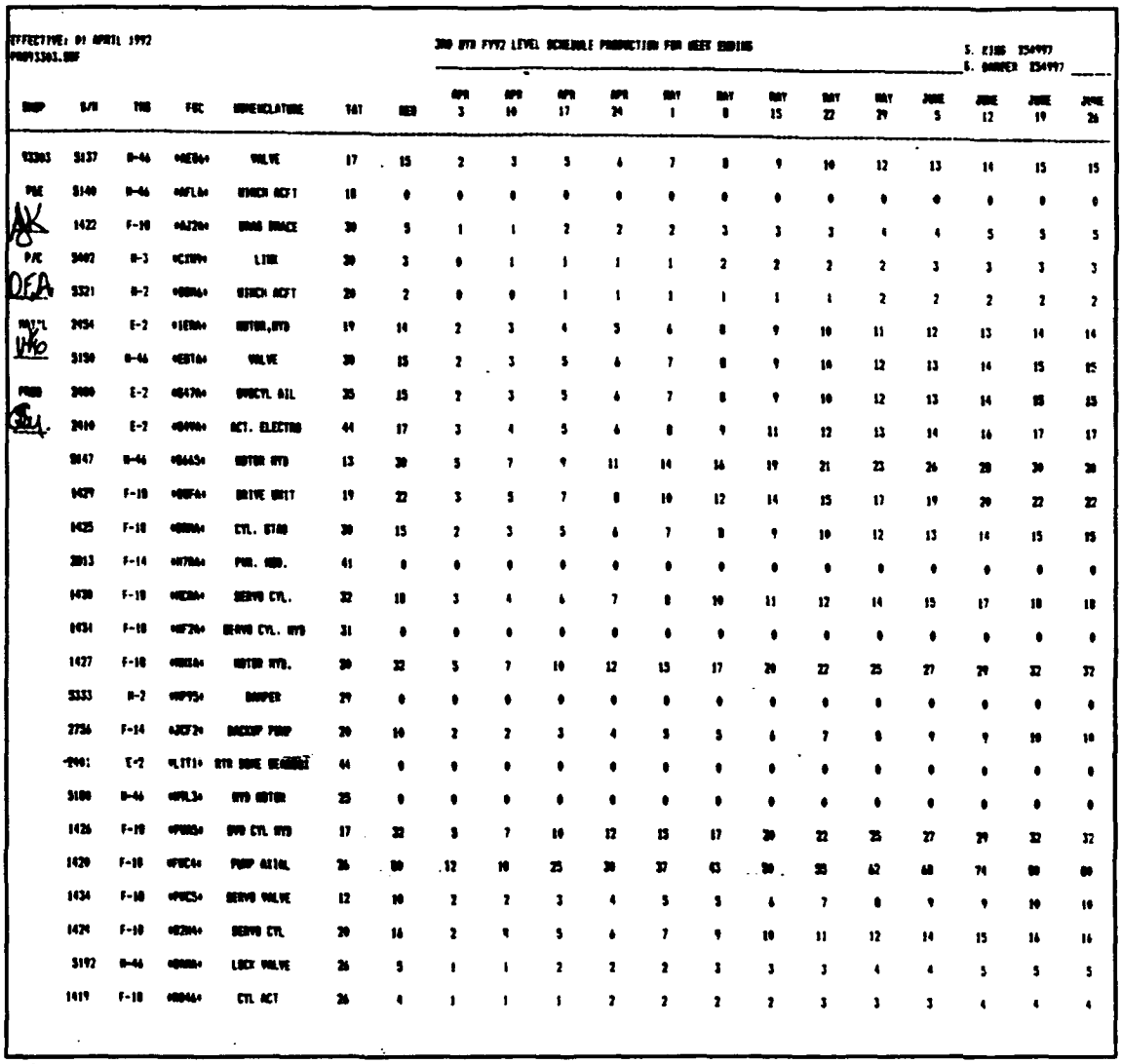
Figure 4-2. Induction Schedule.

To develop an induction schedule, the P/E looks at the standard TAT allowed for each item, subtracts that time from

the available time in the quarter, and then divides the number of jobs by the remaining time to determined the rate in which the shop must induct the jobs. For example, if the negotiated workload called for Shop 93302 to produce 100 pumps that had a standard TAT of three weeks, the shop would have to induct 10 pumps per week in order to complete the requirement before the end of the quarter (note that each quarter consists of 13 weeks and that this example assumes all items inducted can be repaired). The P/Es then post the completed induction schedules in the CCCs and track the progress of the shops during the quarter.

The P/Es develop a production schedule for the quarter as well. They use the induction schedule as the start point for the production schedule. They figure in the standard TAT and determine the rate at which the shops must complete the jobs in order to meet ASO's requirements. This schedule, like the induction schedule, is posted and tracked throughout the quarter. Figure 4-3, shows the component production schedule Shop 93303 must meet for 3rd quarter, FY92. It shows the cumulative number of components that must be produced by the date shown in each week of the quarter.

A percentage of the AVDLRs inducted into the depot will be found to be Beyond the Capability of Maintenance (BCM); i.e., beyond repair. Components are BCM'ed because the cost to repair them exceeds the authorized cost limits imposed by Navy Aviation Depot Headquarters Command. This situation presents



EFFECTIVE: 01 APRIL 1992
P0091303.DAT

300 BYD FY92 LEVEL SCHEDULE PRODUCTION FOR HEAT SHIELDS

S. FINS 154997
S. DAMPER 154997

SHOP	S/N	TMS	FSC	NOMENCLATURE	TAT	REQ	APR 3	APR 10	APR 17	APR 24	MAY 1	MAY 8	MAY 15	MAY 22	MAY 29	JUNE 5	JUNE 12	JUNE 19	JUNE 26
93303	3137	B-46	4EB6*	VALVE	17	15	2	3	5	6	7	8	9	10	12	13	14	15	15
PSE	3140	B-46	4EFL6*	BRANCH ASSY	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AK	1422	F-10	4A29**	BRAG BRACE	30	5	1	1	2	2	2	3	3	3	4	4	5	5	5
P/C	3402	B-3	4C1B9*	LINE	30	3	0	1	1	1	1	2	2	2	2	3	3	3	3
DFA	3321	B-2	4BBN6*	BRANCH ASSY	20	2	0	0	1	1	1	1	1	1	2	2	2	2	2
HYD'L	2454	E-2	41EB8*	MOTOR,HYD	19	14	2	3	4	5	6	8	9	10	11	12	13	14	14
HYD	3150	B-46	4EB16*	VALVE	30	15	2	3	5	6	7	8	9	10	12	13	14	15	15
PUMP	2000	E-2	4B47B*	DIRECTL OIL	35	15	2	3	5	6	7	8	9	10	12	13	14	15	15
SOL	2010	E-2	4B490*	ACT. ELECTRO	44	17	3	4	5	6	8	9	11	12	13	14	16	17	17
	3047	B-46	4B65A*	MOTOR HYD	13	30	5	7	9	11	14	16	19	21	23	26	28	30	30
	0429	F-10	4B8F6*	DRIVE UNIT	19	22	3	5	7	8	10	12	14	15	17	19	20	22	22
	0425	F-10	4B8N6*	CYL. STAB	30	15	2	3	5	6	7	8	9	10	12	13	14	15	15
	2013	F-14	4H7B6*	PUR. HOD.	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0430	F-10	4HEB6*	SERVO CYL.	32	18	3	4	6	7	8	10	11	12	14	15	17	18	18
	0434	F-10	4HF26*	SERVO CYL. HYD	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1427	F-10	4HH56*	MOTOR HYD.	30	32	5	7	10	12	15	17	20	22	25	27	29	32	32
	5333	B-2	4HP95*	DAMPER	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2756	F-14	4JCF2*	BACKUP PUMP	20	10	2	2	3	4	5	5	6	7	8	9	9	10	10
	2001	E-2	4L1T1*	HYD BRAKE [illegible]	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5100	B-46	4PPL3*	HYD MOTOR	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1426	F-10	4PW8D*	HYD CYL HYD	17	32	5	7	10	12	15	17	20	22	25	27	29	32	32
	1429	F-10	4PXC4*	PUMP AXIAL	26	80	12	10	25	30	37	43	50	55	62	68	74	80	80
	1434	F-10	4PXC5*	SERVO VALVE	12	10	2	2	3	4	5	5	6	7	8	9	9	10	10
	1429	F-10	4R2B4*	SERVO CYL	20	16	2	4	5	6	7	9	10	11	12	14	15	16	16
	5192	B-46	4R4B8*	LOCK VALVE	26	5	1	1	2	2	2	3	3	3	4	4	5	5	5
	1419	F-10	4R846*	CYL ACT	26	4	1	1	1	2	2	2	2	3	3	3	4	4	4

Figure 4-3. Production Schedule.

special problems for P/Es when developing induction and production schedules. If the requirement from ASO is to produce 100 hydraulic pumps for the quarter and those pumps have a BCM rate of 10%, the P/Es must induct 110 pumps to meet the requirement. However, the BCM rate is only an averagze and the actual rate will fluctuate from quarter to quarter.

P/Es use their past experience with the items and tend to schedule more inductions up front so they can get a "feel" for the actual number of inductions needed to meet production requirements (King, 1992). Of course, their estimates are not always correct. This sometimes results in a large number of additional inductions near the end of the quarter which require overtime labor to complete on time. We reviewed eight quarters of workload history and saw this trend in several shops.

E. SUMMARY

Production planning and scheduling is primarily done by the P/Es in the CCCs. PMTOs are also very interested with the process since they deal with the customers on a daily basis. The hardest part of the process is determining how many items to induct to meet the production requirements of the Component Section's primary customer, ASO. BCM rates for the various components add complexity to the process of developing induction and production schedules for the shops.

V. PRODUCTION CONTROL

In this chapter we will look at how the Component Section currently controls the flow of jobs through the shops. We will describe the roles of the key players and the tools used to control job flow.

A. INDUSTRIAL ENGINEERING TECHNICIAN

The Industrial Engineering Technician (IET) plays several key roles within the Component Section of the depot, as outlined in Chapter II. To summarize, the IET is primarily involved in managing the industrial capacity of the depot in terms of shop layout, production flow, and production standards. For the purposes of production control, the IET develops and maintains workplans for every AVDLR the depot repairs. The workplan, also know as Master Data Record (MDR), is the base document used to control the flow of components through each shop. The IETs determine how the item should flow through the shops and how much time it should take to complete each repair task. The IET incorporates this information along with other technical and pricing data into the MDRs. The rest of this chapter will discuss the information annotated in the different sections of the MDR.

B. MASTER DATA RECORD (MDR)

The MDR is a document that contains all relevant data about a particular item or component. Data in the MDR is used to produce shop orders, job cards, and WIP records. These documents, in turn, are then routed through various computer subroutines to provide data for planning, scheduling, workload history, cost accounting, and numerous operating reports.(Vest, 1992) Some of the more common outputs are: (1) Updated Master File, (2) Change Reports, (3) Change Error Reports, (4) UADPS cards, and (5) Analytical Maintenance Program (AMP) paperwork. We will cover some of these outputs in more detail throughout the thesis.

An MDR is developed for every type of component and end item repaired at the depot. Component MDRs are linked to end item MDRs. As a result, industrial engineers have visibility of all components that affect the end item. In fact, much of the information contained in the component MDR is used in building the end item MDR. In theory, once an MDR is prepared correctly, it shouldn't change. However, an MDR may change if there is a change in the required maintenance tasks or a change in the shop layout.

Information contained on the MDR is separated into four major groups. They are: (1) part identification group; (2) technical data group; (3) miscellaneous information group; and (4) load and schedule group. For routing, scheduling, and

control, we are primarily concerned with the technical data group and the load and schedule group.

1. Part Identification Group/Control Group

This group contains information that identifies the generic component, the program the component belongs to, control/condition codes, computer generated source or error codes, accounting data, and other information. This information is key for accessing the MDR and generating various management reports.

2. Technical Data Group

The technical data group contains all technical data relating to the component. It is critical that this portion of the MDR be annotated correctly. It is the most important tool used in ensuring adequate processing of aircraft and AVDLRs through the depot.

Technical directives which change or modify established routing and flow time through the shops are recorded in this section. A technical directive is the authorized medium for recording modifications on Navy equipment. Four types of changes may be found in this section. They are: (1) formal changes; (2) interim changes; (3) bulletin items; and (4) Rapid Action Minor Engineering Changes. Also included in this section are Local Engineering Directives (LED). These are informal changes that supplement, augment, or correct existing technical data (NADEP NI, 1988).

3. Miscellaneous Information Group

This group contains information that does not go into any other group on the MDR.

4. Load and Schedule Group

By far, the most important group for routing, scheduling, and control of AVDLRs repaired at the depot is this group.(Kirchman, 1992) It contains the vital information used by P/Cs for these functions. It includes the routing sequence for the component through the shops, standard flow times for maintenance, administrative delay time, a description of the operations each shop must perform, scheduled TAT, standard hours for pricing data, flow time between the shops, and other related data. With this information, workload planners and estimators, as well as production controllers, can identify critical paths the component must follow and exercise the appropriate management control to ensure smooth flow through the shops. The main output that contains this information, needed by production controllers, is the UADPS card.

C. SCHEDULING FACTORS ON MDR

To more fully understand how to use the scheduling factors on the UADPS card, we have included an explanation with an example.

Scheduling factors are calculated by computer routine for the UADPS card. The MDR is the start point for this data.

The handling and flow times from the MDR are converted and printed on the UADPS card in the form of start factor, end factor, and completion hour. The start factor is the number of days between the day of induction and the day the operation is scheduled to start. Thus the start factor for operations which are started on the first (induction) day is 00, second day is 01, third day is 02, etc. The end factor is the number of days between the day of induction and the day the operation is scheduled to be completed. The start and end factors are commonly referred to as start and end days for easy understanding (NADEP NI, 1988). Completion hour times are expressed in two characters (08, 12, 20, instead of 0800, 1200, 1600, 2000). Only on-the-hour times are used. For computation purposes, work shifts are: first or day shift from 0800 to 1600; second shift from 1600 to 2400; and third shift from 0000 to 0800.

The following example details how to interpret the scheduling factors on a UADPS card. Example:

Shop no.	Handling Time	Flow Time	Shift Limiter	Start Factor	End Factor	Compl Hour
A*	04	016	1	00	02	12
B**	04	008	2	02	03	20
C***	08	012	Blank	05	06	12

* - The part moves (during 04 hours Handling Time) from the induction point to shop "A". The Flow Time Start Hour is 12 on day 00. Therefore, 4 hours of Flow Time is scheduled on day 00, 8 hours is scheduled on day 01, and 4 hours are scheduled on day 02. This makes the Completion Hour 12 on day

02. A shift limiter of 1 means that repair is performed on the first or day shift only.

** - Shop "B" has a Shift Limiter of "2" (Second Shift only). Therefore, Handling Time and Flow Time are treated as occurring on the second shift only. The part was completed in Shop A at 12 on day two, but it cannot move until 16 on day 02. Therefore, 04 hours Handling Time in shop "B" commences at 16 and ends at 20. Four hours of Flow Time is used on day 02 and four hours on day 03 commencing at 16. Completion Hour therefore is 20 on day 03.

*** - Shop "C" has a Blank Shift Limiter (all operations are automatically scheduled for day shift only just as though a Shift Limiter of "1" were used). The eight-hour Handling Time commences at 08 on day 04 and ends at 16 on day 04. Flow Time commences at 08 on day 05 and ends at 12 on day 06.

The above example was extracted from the Workplan Management Reference Manual.

D. UADPS CARD

The Master Data Report is the source of all data fields used in generating the Uniformed Automated Data Processing System (UADPS) cards for each component and sub-component that is processed through the NADEP. The cards are computer generated by the Planner and Estimator (P/E) within the Component Control Center (CCC). The production controller physically attaches the UADPS card with the appropriate fields to the component. UADPS cards provide identification, routing information, labor work standards, technical data and inspection points. Eventually, UADPS data is routed to the Master Component Rework Control (MCRC) database which is used by ASO for making depot overhaul cost comparisons.

When a piece of equipment is inducted into the depot for repairs, a UADPS card is generated from the data base. This card is attached to the DLR and follows the DLR through each of the shops. When a DLR enters the shop, the technician completes the repair, then stamps and dates the card appropriately in the last column of Figure 5-2. The component is then moved to the next shop on the routing sequence and the process is repeated until the equipment is repaired and "sold"[5] back to the customer. When the components leaves the depot, information from the UADPS card is transferred to the WIPICS database (discussed later in this chapter) and the card is destroyed.

Routing between the shops is the responsibility of the production controllers for the section that just completed the work. For example, in Figure 5-2 shops 93302 is responsible for moving the part to shop 97402 at the completion of the line 4 operation. They also prioritize the work as it moves from shop to shop. However, delays in transporting components between shops routinely occur since Public Works controls the physical movement of the components between shops.(CDR Pyle, 1992) Because Public Works falls outside the NADEP chain of command, moving equipment between shops can consume more time than the actual repairs on some components.

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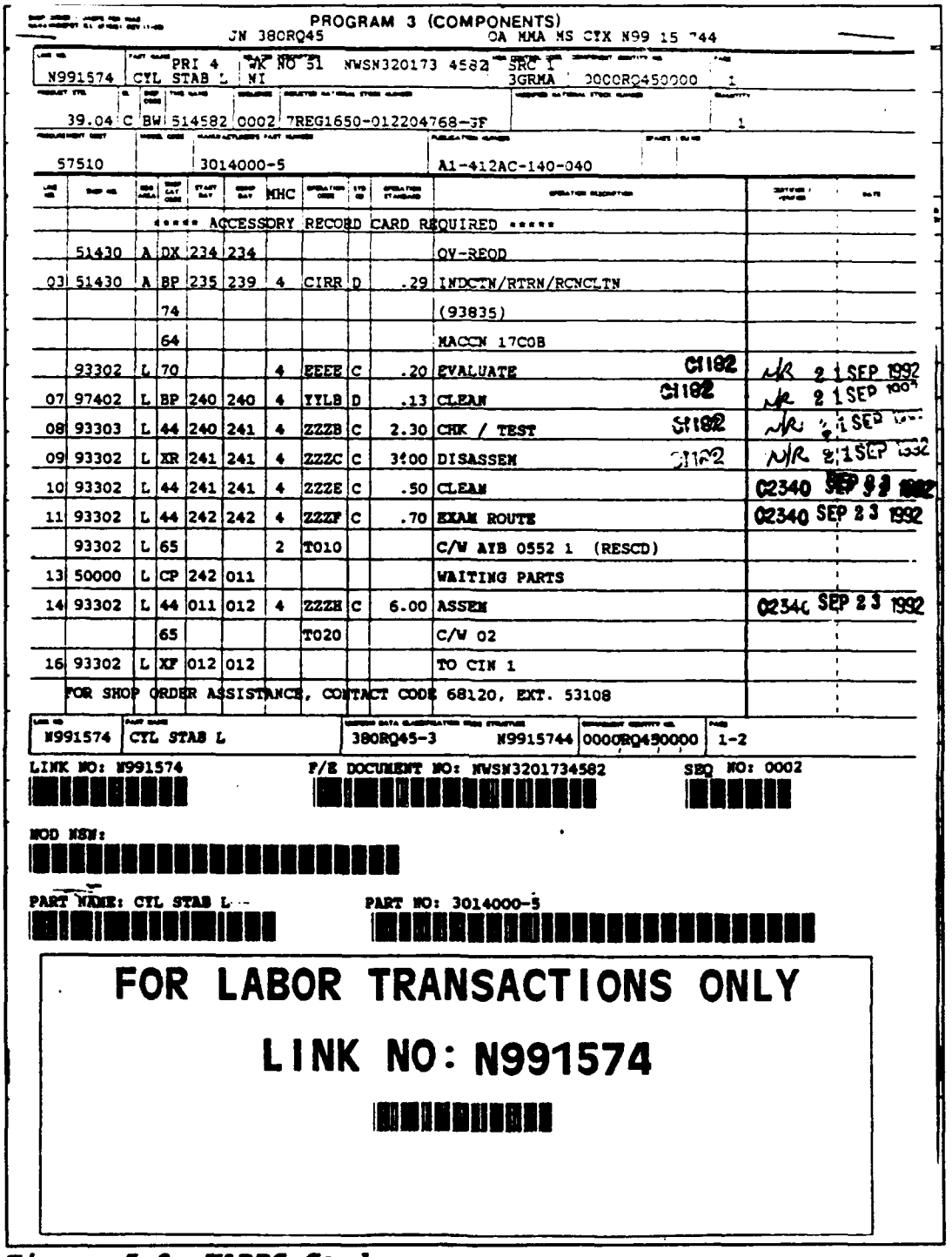
[5] NADEP colloquial for Ready-for-Issue components with shipping status.



PROGRAM 3 (COMPONENTS)

JN 380RQ45 OA MMA MS CTX N99 15 744

N991574	CYL STAB L	PRI 4 NI	WR NO 51	NWSN320173 4582			SRC 1 3GRMA	0000RQ450000	1		
39.04	C	BW	514582	0002	7REG1650-012204768-3F				1		
57510			3014000-5				A1-412AC-140-040				

									***** ACCESSORY RECORD CARD REQUIRED *****		
	51430	A	DX	234	234				OV-REOD		
03	51430	A	BP	235	239	4	CIRR	D	.29	INDCTN/RTRN/RCNCLTN	
			74							(93835)	
			64							MACCN 17C0B	
	93302	L	70			4	EEEE	C	.20	EVALUATE C1182	NR 21SEP 1992
07	97402	L	BP	240	240	4	YYLB	D	.13	CLEAN C1182	NR 21SEP 1992
08	93303	L	44	240	241	4	ZZZB	C	2.30	CHK / TEST C1182	NR 21SEP 1992
09	93302	L	XR	241	241	4	ZZZC	C	3.00	DISASSEM C1182	NR 21SEP 1992
10	93302	L	44	241	241	4	ZZZE	C	.50	CLEAN	C2340 SEP 23 1992
11	93302	L	44	242	242	4	ZZZF	C	.70	EXAM ROUTE	C2340 SEP 23 1992
	93302	L	65			2	T010			C/W AYB 0552 1 (RESCD)	
13	50000	L	CP	242	011					WAITING PARTS	
14	93302	L	44	011	012	4	ZZZH	C	6.00	ASSEM	C2340 SEP 23 1992
			65				T020			C/W 02	
16	93302	L	XF	012	012					TO CIN 1	

FOR SHOP ORDER ASSISTANCE, CONTACT CODE 68120, EXT. 53108

N991574	CYL STAB L	380RQ45-3 N9915744	0000RQ450000	1-2

LINK NO: N991574 [redacted] F/E DOCUMENT NO: NWSN3201734582 [redacted] SEQ NO: 0002 [redacted]

MOD NSN: [redacted]

PART NAME: CYL STAB L [redacted] PART NO: 3014000-5 [redacted]

FOR LABOR TRANSACTIONS ONLY

LINK NO: N991574

[redacted]

Figure 5-2. UADPS Card.

The routing sequence on the UADPS card is generally fixed. Deviations from the routing sequence rarely occur and for most

AVDLRs are not possible. The result is that bottlenecks[6] frequently occur in some of the more critical shops.

Some of the components repaired in the component section of the depot have to go through as many as 10 or 15 different shops before they are completely repaired. Production controllers strive to ensure that the components move through the shops under their control within the time constraints on the UADPS card. In establishing the time constraints for each shop, the model used assumes that all parts needed to make the repairs are on hand and available. Therefore, there is no time built in for waiting for parts.

Under the current procedures, one shop is designated as the primary shop and has the responsibility to monitor the progress the AVDLR is making through the system. The designated shop is normally the one who disassembles and assembles the component after initial inspection. The shop with this responsibility has an "XR" in the shop category code section on the UADPS card.(NADEP NI, 1988)

E. WORK-IN-PROCESS-INVENTORY-CONTROL-SYSTEM (WIPICS)

The Work-In-Process-Inventory-Control-System (WIPICS) is a computer program used by P/Cs and material specialists to track and control their workload in the depot. "WIPICS tracks

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[6] Refers to a resource where the demand for that resource exceeds the capacity of that resource.

the location, progression, inventory and status of aircraft and manufacturing work-in-process and their components and assemblies in maintenance at different locations within the NADEP."(NADEP NI, WIPICS, 1991) When a DLR enters the section for repair, the P/C enters the job into the WIPICS data base. As the DLR moves from shop to shop, the P/C updates WIPICS to reflect the most current status of the job. The status of repair parts needed to repair a component is also tracked in WIPICS. Material specialists update the database as they receive repair parts and status of repair parts from the supply system. The WIPICS database does not interface with the supply system's database, so changes must be imputed by the material specialist in the shops. When the DLR is repaired and sold back to the customer, the P/C removes the repair order from the database. Since many of the AVDLRs have sub-components and sub-sub-components that are repaired in various shops throughout the depot, WIPICS is a valuable aid to P/Cs in tracking the status of their jobs. However, the validity of WIPICS data is dependent on P/Cs and material specialists updating the data base regularly and accurately.

F. PRODUCTION STATUS MAPPER SYSTEM

Production Status Mapper System (PS MAPPER) is a data base used by foremen, P/Es, PMTOs, and management personnel throughout the depot. The active portion of the database contains up to six quarters of job history on every shop in

the depot. Management personnel can access this database to get information about completed and in-process work. The data for many of the management reports used to track the depot's performance is extracted from the PS MAPPER database (CDR Pyle, 1992). For production control purposes, the PS MAPPER database keeps track of actual TATs for each AVDLR, material and labor expenditures, the number of AVDLRs produced for a specified time period, the number of AVDLRs not produced for a specified time period and the reason, and the priority of each AVDLR. Much of the information in PS MAPPER database is obtained from the WIPICS database. Since the two are linked, an update to WIPICS automatically updates MAPPER.

The final player in production control is the shop foreman. The primary function the foreman performs is to assign specific jobs to the artisans and ensure those jobs are completed within the time standards. The foreman also manages the artisans and is responsible for ensuring they are trained and capable of performing their jobs. Personnel problems are handled by the foreman.

G. SUMMARY

The primary players in the production control process are the P/Cs, material specialists, the foremen, the IETs, and the PMTOs. The most important role is played by the P/Cs who prioritize the jobs and move them between the shops. Since the material specialists work for the P/Cs, the P/Cs are also

involved in the repair parts process. The P/Cs' primary tools in controlling the process are the WIPICS database and the UADPS cards.

VI. MATERIAL FLOW

In this chapter we will look at an actual material flow. In particular, we will describe how an F/A-18 Horizontal Stabilizer Hydraulic Servo Cylinder (Stab Actuator) flows through the NADEP. The reason for detailing this component's flow is that during thesis research a bottleneck was found in this flow process while we were applying TOC management principles. The Stab Actuator is a level-scheduled AVDLR that flows through the Hydraulic Division's Shop 93302.

A. RECEIVING/SHIPPING SECTION

At the receiving/shipping section the stabilizer is unpacked and the paperwork is checked to ensure the item is suppose to be received at the section. The UADPS card is also attached to the stabilizer here. Once the stabilizer is repaired, the section packs it, checks the paperwork for completeness, and prepares shipping documents to transport the stabilizer back to the customer. The MDR time standard for each stabilizer processed by this section is .29 hours each way. During visits to the section, the process generally took longer than the time allotted. This is mostly because it takes two workers to lift the stabilizer onto a cart to move it to the next station. Since there was only one worker at

the section, he had to ask others in the building to help him lift the stabilizer onto the cart.

After completing the process for receiving the stabilizer, the receiving/shipping section notifies the P/C. The P/C then moves the stabilizer to the next work station which is in the cleaning section.

B. CLEANING SECTION

The cleaning section ensures the stabilizer is cleaned of any oils or hydraulic fluid before it goes for repair or testing. The hydraulics shop has its own cleaning section located in the same building so it is relatively easy to move the stabilizer from receiving/shipping to the cleaning section. The MDR time standard for stabilizers processed through this section is .13 hours. During our visits to this section, we saw that most of the stabilizers were processed within the time allotted.

Once the stabilizer is cleaned, the P/C is again notified and must move it to either the repair bench or the servo test stand. Stabilizers received from the supply center are sent to the servo test stand to determine what needs to be repaired. Stabilizers received from overhauled aircraft must be rebuilt and therefore go straight to the repair bench if all repair parts are on hand. Because the majority of the stabilizers that Shop 93302 repairs comes from the supply system, we will treat our example as such.

C. INITIAL TESTING

While in Shop 93302, the stabilizer undergoes tests and checks to determine what repairs are needed. The MDR time standard for testing on the STS is 2.3 hours. According to the technician and our own observations, the test takes a little over 3 hours to conduct on average (Gwizdak, 1992). Once the stabilizer is attached to the test stand, the test is fully automated. However, by regulation, the artisan must monitor the test to perform periodic trouble shooting. The servo test stand also requires 30 minutes set up time for testing the stabilizer. Because of this setup time, the artisan will normally wait for a batch of 6-7 stabilizers before setting up the test stand to test the stabilizers (Gwizdak, 1992). Once the test is completed the artisan checks the stabilizer and reviews the test printout results to determine the extent of repairs required.

During visits to this work station, we observed the same problem of lifting the stabilizer as we saw in the receiving section. The artisan at this station needed the help of another artisan to lift the stabilizer to and from the test stand. On several occasions the test stand remained idle because there was no one available to help the artisan lift the stabilizers to and from the test stand.

D. MATERIAL SECTION

Once testing is complete and the extent of repairs determined, the P/C must check to see if repair parts are available to perform the needed repairs. If repair parts are unavailable, the stabilizer is moved to the material section while awaiting parts. At this point, the material specialist must check on the status of the needed parts to ensure their expected delivery date (EDD) is within 45 days of order. Any stabilizers whose repair parts are expected to arrive after more than 45 days are put into "G" condition and shipped back to the supply center (Vest, 1992). For stabilizers whose repair parts have EDDs of less than 45 days, the material specialist will establish a location in his storage area for the stabilizer and its repair parts. Once the repair parts are received, the P/C will move the stabilizer and its parts to the repair work center.

During our visit to the P/C and material specialist work center, we saw a number of stabilizers as well as other jobs that should have gone into "G" status for lack of repair parts but had not. We also observed about 5 days of work was waiting to be moved to the test stands.

E. REPAIR SHOP

Following testing and checking, the stabilizer is moved to one of the shops where the repairs are performed. The foreman assigns the stabilizer to an artisan who will do the repairs.

The artisan uses the information generated by the testing station to determine the repairs needed. At this station, the stabilizer is disassembled, repaired and re-assembled. Once the repair is completed, the stabilizer is moved back to the servo test stand for final testing. The MDR time standard for disassembly, repair and re-assembly of the stabilizer is 9 man-hours.

From our observations and checks, it appears that on average the stabilizers are repaired within the time standards allowed on the MDR. However, by checking UADPS cards, we observed quite a few stabilizers having to be repaired 2-3 times before they would pass final testing. Re-working jobs is fairly common practice in Shop 93302.

F. FINAL TESTING

The stabilizer is moved back to the servo test stand for final testing. The same test procedures are used for final testing as were used in initial testing (see above).

G. X-RAY

A change to the repair manual issued about six months ago required all stabilizers to be x-rayed. This is to ensure the Main Ram Linear Variable Differential Transformer (LVDT) on the stabilizer is properly connected. The X-Ray Section is located in a different building from Shop 93302 so the P/C has to coordinate with Public Works to move the stabilizer to the

X-Ray Shop. Once the x-ray is completed, the job is moved back to the receiving/shipping section in the Hydraulics Shop for final QC before shipping it back to the customer.

Moving equipment between shops is always costly in terms of time. We were told by several workers that a lot of time is wasted waiting for the items to be moved to and from the X-Ray Section. Normally, the stabilizers won't be moved to the X-Ray shop until a full pallet is ready to be moved. It is not uncommon to have 3-4 stabilizers sitting for several days waiting to be moved.

H. SUMMARY

The smooth flow of material through the shops is critical for ensuring acceptable repair TATs. Every shop or section that material flows through needs to aggressively strive to meet the prescribed time standards. Compared to many of the AVDLRs repaired in the Component Section, the stabilizer has a fairly simple routing sequence. Yet, even with its simple routing sequence, we observed processes and practices that slowed the rate of flow of the stabilizer at almost every station along its route. Each of these added time to the stabilizer's repair cycle and created complexity[7] in the

[7] Complexity refers to any extra steps in a process which are really not needed to do the process. The more steps incorporated into a process, the more opportunities there are for mistakes to occur.

process. The result is that actual TATs are consistently exceeding acceptable time standards.

VII. ANALYSIS

A. INTRODUCTION

In this chapter we will describe how we applied the TOC management principles to two work centers within the Hydraulic Division of the depot. We will also show how many of the repair processes and procedures currently used actually reduce flexibility within the shop and unnecessarily increase repair turnaround times. It is paramount for the reader to understand that the people in the Hydraulic Division are competent, skilled professionals. Our purpose is to analyze the repair process and the procedures, not the people! And finally, we will discuss opportunities for improvement that we believe will add flexibility and reduce repair turnaround times.

Our goal in applying TOC management principles was to avoid the trap of applying complex solutions to relatively simple and straightforward problems. We wanted to exploit the resources currently available before we spend dollars acquiring more resources. It's quite possible that once we exploit what we have, we may not need additional resources. These suggestions for improvement may not, however, be simple to implement. Before some of them can be implemented, some institutional thinking must change. Therefore, the challenge

of management is to lead the way in making the necessary changes to institutional inertia.

B. IDENTIFYING THE SYSTEM CONSTRAINT

1. Manual Method

The first and most important step is to identify the system constraint. There are several ways to do that as discussed in Chapter II. Since the depot is composed of hundreds of shops and work centers, we used the manual method to help focus our efforts in finding the constraint. The manual method consists of gathering information by walking around and talking to management and shop personnel. We started at the Component Section PMTO level talking to the various component coordinators. In general, we focused our discussions by asking members of the PMTO where they were having problems meeting induction/production schedules, where work tended to back up, which components had the highest priorities from ASO, and which shops seemed to require a lot of management's attention. The feedback we received enabled us to narrow our initial search to two shops. These shops, 93303 and 93302, mainly perform hydraulic component repair and testing.

Next, we visited these shops and talked to the P/C, P/E, IET, foreman, material specialists, and the artisans. We walked through each work station and paid particular attention to work-in-process at each station. Virtually every person we

talked to said the same thing; that the shop was overworked and undermanned. The amount of WIP we found at each station appeared manageable except at the cleaning station. At that particular station, we found 6 five-shelf carts of WIP (the shop foreman estimated two weeks worth of WIP (Maycott, 1992)). We discovered that this WIP was waiting to be moved to initial testing stations. The P/C, responsible for moving WIP between stations, knew about the work but was unable to move it because the test station had too much backlog. The WIP storage area at the test stands was also completely full. This gave us our first indication that we could have found a constrained resource; the Servo Cylinder Test Station (STS). We next talked to the artisans who operate the three STSs. They complained that they were seldom able to keep up with the workload at these stations. They were short-handed and had to work a lot of overtime. They also related that it took anywhere from 2 to 8 hours to conduct a test depending on the component tested.

2. Data Collection and Plant Type Method

To verify the results of the manual method, we applied some of the techniques of the data collection method to the suspected constraint. That method consists primarily of gathering and using information from the existing management information systems used by the depot. We checked both the

WIPICS and PS MAPPER data bases for data that would support our suspicions.

First, we found that the P/C had routinely inhibited work coming into the Shops 93302 and 93303. In fact, the average amount of workload inhibited was nearly 1,000 hours of work each week due to lack of capacity for the last three quarters of FY 92 (King, 1992). Second, the foreman told us that she routinely works her STS technicians overtime to keep up with the workload (Maycott, 1992). Third, PS MAPPER TAT computations for the last six quarters show that actual TAT exceeds standard TAT for nearly every component that goes through the STS. Fourth, the MDRs of components tested on the STS showed that testing times constituted the majority of the maintenance time of those items. Fifth, we did some rough capacity calculations that indicated the STSs were capacity constrained compared to the other resources in the shop, given the current test procedures and methods. Lastly, when the depot became the Navy's F/A-18 single-site repair facility, the initial site and capacity survey, performed by the depot and NAVAIR, recommended six STSs to meet the anticipated demand (Site and Capacity Survey,) (Gwizdak,1992). NADEP NI has three at present. This is a possible indication that either demand has decreased, efficiency has increased or WIP must be building somewhere.

Based on the information and data obtained, we concluded that for the current repair policies and procedures,

the Servocylinder Test Station was the constraint or bottleneck resource for all components that must be tested on it.

C. EXPLOITATION/UTILIZATION OF THE SYSTEM CONSTRAINT

The next step is to exploit and/or ensure full utilization of this system constraint or bottleneck. This insures the system produces the maximum possible throughput. Therefore, we focused our attention on ways of increasing its capacity and keeping it producing.

Prior to exploitation/utilization of the constraint resource, a necessary condition is that all personnel in Shop 93302 and 93303, the CCC, and in the PMTO, be familiar with basic TOC management principles. This will lead to a fundamental understanding of the importance of keeping the STSs (the bottleneck resource) working on items that generate sales for the depot. Keeping those test stands operating makes intuitive sense once everyone in the shop understands that throughput, the rate at which components are repaired, is dictated by the test stands. Presently, management and shop personnel are not be aware of the importance of these resources, so their thinking is not focused on keeping the test stands producing. As a result, most of people's creative energy is focused elsewhere. It is particularly important that the artisans and the first-line supervisors understand the basic TOC principles since experience shows that those

closest to the process can provide many of the best and cheapest solutions.

1. Staggering Breaks

One method of ensuring full utilization of the STS is to stagger the artisans' work breaks. In the book, The Goal, Goldratt and Cox make the same suggestion. Current test and safety procedures call for an artisan to be present when the STS is operating. The nature of the test is such that periodic troubleshooting may have to be performed on the component during test and the 3000 PSI system pressure requires an ever present safety monitor. To ensure that the bottleneck is operating, an artisan must be present. On a typical day, the artisans are allowed two break periods of 15 minutes each and a 30 minute lunch break. The current procedures as described above, potentially rob the system of three hours of capacity daily. Staggering work breaks is a way to ensure an artisan is always present and will add 1 hour per day of capacity to each test stand or approximately a total of 200 hours per quarter for all three STS's.

2. Initial Testing - Is It Really Necessary?

Another way to save time on the bottleneck is to repair the component before initial testing. Currently, every component that comes through the Shop 93302 must be tested at least two times via the routing and repair sequence on the

component UADPS cards[8]; an initial test to determine the faults and a final test to ensure compliance to specifications. Deviations from the UADPS card routing and repair sequence are prohibited by depot policies (NADEP NI, 1988). In general, this policy was implemented for safety and quality control reasons (Martinez, 1992). But, is initial testing the only way to determine component faults? In some cases, yes! But it may not be for the majority of the cases. By keeping data on the types of faults that most frequently occur on each type of component, we may find patterns or trends that allow us to satisfactorily repair a majority of the items without conducting an initial test. The bottom line is that we are potentially testing more than is necessary and consequently reducing system throughput.

The first step in determining if we are losing system throughput is to keep statistics at the work benches and at the test stands. Each time a component is initially tested, the artisan annotates the fault until a pattern or trend emerges. If a trend on a component emerges (i.e., replacing a certain seal repairs the component 80% of the time), then the cost of unnecessarily replacing that seal 20% of the time can be compared to the resulting savings on the STS. Since any savings on the STS can translate directly into throughput,

[8]Installed components from overhauled aircraft are the only exceptions. These components must also be overhauled so they only undergo final testing. However, installed components make up less than 10% of the shop's work load.

the benefit to the depot is the additional sales that results from the saved time on the STS. If the benefit is greater than the cost, then we can forego the initial testing. Additionally, TAT on the component is reduced by the amount of testing and handling time that would have been used for initial testing. The reduced TAT ultimately results in a higher readiness rate for that component (Trietsch, 1992c).

3. Quality Control

Another way to exploit the bottleneck is to ensure it doesn't process defective components due to poor process control. A significant problem in Shop 93302 is the relatively large amount of repeat testing done on certain components repaired in the shops. Many of these components must be tested on the STSs, resulting in lost time on the system's bottleneck. It's not uncommon for some components to be tested 3 or 4 times before passing the test (Gwizdak, 1992). Even a small reduction in the number of repeat tests would result in a significant increase in throughput. Table 7-1 shows the effect of a 25% reduction in the number of components requiring re-testing given an approximate average testing time on the STS of 3.5 hours. The number of jobs "re-tested" is also an approximation based on input from the artisans who operate the test stands.[9] The table shows a

[9] Currently no statistics are compiled on items requiring re-tests. The numbers in Table 7-1 range between the high and low estimates of the artisan for an average quarter's workload.

range of hours that potentially could be saved on the bottleneck.

TABLE 7-1: EFFECT ON THE BOTTLENECK OF A 25% REDUCTION IN RE-TESTED JOBS

(1) # COMPONENTS RE-WORKED	(2) # RE-WORKED AFTER 25% REDUCTION	(3) COLUMN (1) - (2)	(4) HOURS SAVED ON BOTTLENECK
10	7.5	2.5	8.75
25	18.75	6.25	21.875
50	37.5	12.5	43.75
75	56.25	18.75	65.625

Improved repair processes and statistical process control (SPC) techniques may provide the means for realizing the savings illustrated in the Table 7-1.

a. Quality Control Before Final Testing Is Essential

All components currently repaired in the Hydraulic Shop must be tested before they are sold to the customer to ensure: (1) high quality; (2) compliance to specifications; and (3) compliance with safety standards (Component MDRs and Gwizdak). The artisans who operate the STSs, proudly see their job as ensuring high quality within the shop.

> Quality is absolutely essential in this shop. Most of the components repaired in the shop belong to the F/A-18 Aircraft. If a component fails because of poor quality, a Navy pilot will probably die! Exacting standards are a must here. (Gwizdak, 1992)

What this means is that final testing will continue to comprise a significant amount of the total repair time of components going through the Hydraulic Shop. Because of this, testing time on the STS must be used effectively.

One way to ensure STS time is used effectively is to ensure the system constraint doesn't process components that fail to meet quality standards and specifications. This means that quality must be monitored, controlled, and improved at each step in the repair process. "The responsibility for quality rests with the makers of the part or providers of the service. In other words, in total quality control, primary responsibility for quality resides in operations." (Schonberger and Knod, 1991) The artisan who operates the machine or who repairs the component plays the key role in providing a quality product or service. He is responsible for implementing what Schonberger refers to as "the process improvement cycle[10]". The bottom line for the shop and the depot is that there is no benefit to the system in testing components that we should have known ahead of time would fail the test a second time.

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[10]The process improvement cycle is the process of improving a product or service by measuring, controlling for consistency, and improving the process (Schonberger and Knod, 1991).

Given that everyone in Shop 93302 is concerned about quality, statistical process control (SPC) techniques[11] are a way to ensure critical repair processes are under control and producing quality parts or services (assuming that the machine is capable of performing the operation within the necessary specifications). During our visits, we did not observe the use of any SPC techniques within the Shop 93302. We suspect that part of the reason for the large number of re-tests, results from processes that are out of control or processes not capable of consistently meeting established specifications. The implementation of some SPC techniques may eliminate some of the "re-testing" with the resulting savings in testing time. Some processes that may lend themselves to these techniques are the nickel plating operations and the machining operations that support Shops 93302 and 93303. Determining the exact techniques to use and on which processes to use them on is beyond the scope of this thesis. The main point is that using SPC techniques is a way to exploit the bottleneck and is worth further study. Personnel in the Process Improvement Office and Quality Control Section of the depot may be able to assist the shops in the implementation of SPC.

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[11]There are a number of well written books on SPC that the reader can use to further explore this subject. Some are listed in the reference section of this thesis. For a quick overview of various SPC techniques, see "Operations Management, Improving Customer Service," Chapter, 15 by Schonberger and Knod, 1991.

4. Repair Part Considerations

Another way to exploit the STS is to ensure all repair parts needed for components are on hand or available within prescribed time standards before processing the jobs through the STS. Under current procedures, if parts are not available within 45 days from the date of order, the P/C puts the component into "G" condition and ships it back to the supply center until the parts become available. Normally, the component has at least been initially tested before going into "G" condition. Once parts are on hand, the components are suppose to be sent back to the shop for repair. In practice, anywhere from 10% to 50% of the components are not job ordered back to the depot[12]. These components can not be considered throughput. The depot gets no credit for "G" conditioned jobs. Components tested on the STS that can't be repaired for lack of repair parts result in lost time on the bottleneck.

Even components that are re-job ordered to the depot once repair parts are on hand still waste STS time. These components are tested again on the STS to determine if there are any additional deficiencies. The reason for the re-test is that the components tend to deteriorate and/or are damaged

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[12]These percentages are based on depot FY 92 production data and data extracted from the G-Man data base. G-Man is a stand-alone PC-based data base used by NSCs to track "G" conditioned components and their repair parts. The percentages vary among components. These percentages represent the high and low percentages.

during storage and transport. Corrosion is the primary problem (Gwizdak, 1992). Often the items are not packaged and preserved properly. Additionally, NSC San Diego personnel many times cannot store the components in warehouses because there is simply not enough storage space. All of these things aggravate the corrosion problem. The point is that the components must be re-tested and the re-test wastes STS time.

At present, managers and shop personnel take several steps to minimize the number of jobs that can't be repaired for lack of parts. First, extensive efforts have been made to develop a BOM for each component the Component Section repairs. The idea behind the BOM is to have on hand those parts most often replaced in a component (Fancy, 1992). Second, the P/Es review repair parts availability for level scheduled components prior to the negotiation process with ASO (King, 1992) (Barber, 1992). This review helps highlight repair parts problems to ASO and filters out some components with problems before they are job ordered to the depot. Third, as a last resort, cross-leveling (controlled substitution)[13] or "back-robbing" of parts from one component to another is attempted to keep the component from going into "G" condition (Wood, 1992). Yet, even with these efforts, a significant number of components must be shipped back to the

[13]Cross-leveling or controlled substitution is the process of taking a serviceable repair part off of a component and putting that repair part onto another component.

supply center as unserviceable for lack of parts. Table 7-2 shows the percentage of components most commonly tested on the STS that went to "G" condition. The data is for the most recent past four quarters, 1 October through 30 September of FY 92.

From Table 7-2, we can see that Shop 93302 "lost" a significant amount of throughput during FY 92.

TABLE 7-2: "G" CONDITION STATISTICS FOR SELECTED COMPONENTS

NOMENCLATURE	# JOB ORDERED	# "G" CONDITION	% "G" CONDITION
DRIVE UNIT (GQFA)	60	17	28
STAB ACTUATOR (GRMA)	187	48	26
SERVO CYLINDER (HCRA)	65	10	15
HYDRAULIC SERVO CYLINDER (PWA5)	76	8	10
SVO VALVE (Q2H4)	35	7	20

The same data plus some additional data was used to develop Table 7-3. Table 7-3 shows the actual number of hours that components were run on the STS prior to being put into "G" condition. We can see from Table 7-3 that in FY 92

approximately 260 hours of throughput were lost because of a lack of repair parts.

TABLE 7-3: HOURS LOST ON STS DUE TO PART SHORTAGES

NOMENCLATURE	QTY	TEST TIME*	HRS LOST
DRIVE UNIT (GQFA)	23	2	46
STAB ACTUATOR (GRMA)	48	3.5	168
SERVO CYLINDER (HCRA)	10	1	10
MANIFOLD (HF1A)	3	3	9
HYDRAULIC SERVO CYLINDER (PWA5)	8	1.25	10
SVO VALVE (Q2H4)	7	2	14
SVO VALVE (Q2P6)	1	2.25	2.25
		TOTAL	259.25

* Test time is in hours.

There are several ways we might attempt to decrease those lost hours on the bottleneck. First, for components that will pass through the bottleneck, P/Es can conduct a more thorough review of repair parts availability. The emphasis should be much greater on components that are processed

through the bottleneck than on components which are not. Second, with an understanding of the effects of not having repair parts, higher levels of management can re-direct their focus where they will get the most benefit. They can put pressure on the supply system to respond more rapidly to their requirements. Third, the depth and range of repair parts stocked at the depot can be increased to provide higher service levels for critical parts. There is a proposal being drawn up by the Material Services Division which addresses this range and depth of materials issue. Finally, the simplest and, in the long run, cheapest yet most difficult solution to implement would be for the NSC to hold the component until all anticipated repair parts are available. This should greatly reduce the number of jobs that ultimately end up in "G" condition.

Currently, many components are job ordered to the depot even when parts are not on hand (King, 1992). This usually occurs when ASO anticipates receiving repair parts from a contractor within the 45-day time window for the components they want repaired by the depot. The problem is that lead-times for parts are long and the expected delivery dates are usually unreliable unless the item manager continually follows up with the contractor (Moore, 1992). As a result, the repair parts don't arrive when they are needed. If this happens, then at best, the jobs unnecessarily lengthen the maintenance pipeline causing longer TATs. At worst, the

components go "G" condition causing even longer TATs and costing additional dollars to package, store, and ship the items back to the supply center.

The cycle described above is hard to break. Congress is partially to blame for the long lead-times for repair parts. Many of the laws they have passed, which are embodied in the FAR, make it nearly impossible to establish close ties with suppliers, a necessary condition for the JIT inventory philosophy. Additionally, ASO is a customer as well as a supplier to the depot. It's difficult to tell your customer that you can not accept his jobs until the repair parts are on hand. Given the expected long and unreliable lead-times for material from contractors, a policy of not job ordering the component until all anticipated repair parts are on hand would significantly alleviate the number of jobs that end up in "G" condition. When lead-times for repair parts are substantially reduced, then this policy could be eliminated.

5. Preventive Maintenance

Another way to exploit the STS is to have an effective and aggressive preventive maintenance program. The idea behind preventive maintenance (PM) is to keep the machines and tools in peak operating condition throughout their operating life. Most literature today discusses PM as a part of Total Quality (TQ). Recently, many companies have rediscovered the importance of preventive maintenance for their operations

(Trietsch, 1992c). "The approach, called total preventive maintenance (TPM) or, sometimes, total productive maintenance, is operator-centered."[14] (Schonberger and Knod, 1991) Many organizations have used operator-centered PM as an effective way to maintain equipment readiness. For years, the military has stressed the importance of operator-centered PM and has achieved impressive results, especially in the areas of combat aircraft, ships, and vehicles. In the context of the system constraint, PM becomes even more important. An inoperative bottleneck means less throughput, longer repair TATs, and ultimately lower readiness rates (Trietsch,1992c).

The benefits of operator-centered PM would help Shop 93302 exploit their system constraint. Currently, the STSs are operated to failure. According to the artisans, when the test stands fail they are generally down for two to three weeks at a time and sometimes even longer (Gwizdak,1992). This results in a lot of lost time on the STSs and lost throughput. At the time of our thesis research, one STS was only partially mission capable. The STS had remained that way for at least three weeks. Because of this condition, no F/A-18 Leading Edge Flap (LEF) assemblies, Hydraulic Drive Units (HDU), or Remote Servo Valves could be tested on that machine.

In our opinion, preventive maintenance for the STSs needs to be addressed. It appears that several departments

[14]Refers to PM that is performed by the operator of the machine or equipment.

own pieces of the program but no one section controls the program as a whole. Almost everyone we talked to about preventive maintenance on the STSs said that there are problems with the program. Most agree that the lack of preventive maintenance is very expensive and disruptive to depot operations. We attempted to quantify the impact on Shop 93302 but were unable to find any current data. If PM is done, records are not kept. Additionally, down time on equipment is also not recorded.

Using PM in Shop 93302 should immediately improve operations and help ensure that the system constraint is exploited. The emphasis should be operator-centered PM. This requires that operators be trained and that records be kept.

6. Setup Time Reduction

Reducing the setup time on the STSs will result in more throughput and shorter repair TATs for the components tested on it.[15] These two reasons alone justify exploring setup time reduction on the STSs. However, there are other benefits of reducing setup that include: (1) increased flexibility of operations; (2) increased productivity; (3) less scrap; (4) reduced requirements for new equipment; (5) higher quality; and (6) smaller time buffers (Trietsch,

[15]The STS is a bottleneck resource that is also on the critical path for the components tested on it. Any savings on the bottleneck due to setup time reduction will result in extra capacity and reduced lead times.

1992b). Because of these multiple benefits, setup time reduction is worth investigating on non-bottleneck resources as well.

In the late 1960s, a Japanese industrial engineer, Shigeo Shingo, developed a methodology for reducing setup times on machines used in manufacturing called "Single Minute Exchange of Die" (SMED)[16]. The goal of SMED is to reduce setup times to under 10 minutes (i.e., to a single digit of minutes). SMED is a three stage process for achieving single digit setups. The three stages are:

1. Separate Internal and External Setups;
2. Convert Internal Setups to Eternal Setups; and
3. Streamline Both Internal and External Setups.

a. Separate Internal and External Setups

Internal setups refer to operations that can only be performed when the machine is not operating. Conversely, external setups refer to operations that can be performed while the machine is operating. The purpose of identifying and separating the two types of setups is to ensure as many external setups as possible are performed while the STS is operating. For example, when moving an F/A-18 Stab Actuator from the storage shop to a position close to the STS prior to testing, we are performing an external setup. The actuator

[16]For a more detailed yet concise explanation see "Some Notes on the Application of Single Minute Exchange of Die (SMED)" by Dan Trietsch, July 1992.

can be moved while the STS is operating on another component. Attaching the actuator to the STS is an internal setup since the test stand can not be operated during the attachment.

Normally, determining which steps can be done while the STS is operating and which cannot, will yield improvements over the current way the setup is accomplished. This first stage of the process is typically inexpensive. Dan Trietsch sums it up best:

> Typically, the first stage requires very small investment in hardware, if at all. Instead, as any other improvement effort, it requires thoughtware, i.e. brain power. The benefit, again typically, is a savings of about 50% of the setup time. (Trietsch,1992b)

b. Convert Internal Setups to External Setups

The purpose of this stage is to reduce setup time even further. Each internal setup must be examined to determine if it can be converted into an external setup. Each internal setup on the STS that is converted to an external setup results in extra capacity on the STS. It may be possible to convert part of the internal setup of attaching the F/A-18 Stab Actuator to the STS to an external setup. Part of the process of attaching the actuator involves attaching three separate electrical connections to the STS. For a very small investment, an electrical wiring harness with quick disconnects could be used on the actuators so that the internal setup consists of only one electrical connection instead of three. This could potentially save 1-2 minutes on

the internal setup. This is only one idea. There are probably many better ideas that people closer to the process could implement to further reduce the setup time. The beauty of this stage is that again like the first stage, brain power is the driving force for improvement.

c. Streamline Both Internal and External Setups

Completing the first two stages of the process should yield increases in STS operation time; resulting from as much as a 75% reduction in setup time.[17] In order to achieve even more reductions, it may be necessary to streamline the setups. Streamlining means reducing the amount of work it takes to do the setups (Trietsch, 1992b). In the first two stages, the amount of work required to setup the STS will probably not change. For example, we will still have to make the same number of electrical connections. The only thing we might be able to do is shift the work from an internal setup to an external setup. Further reductions will probably require streamlining the setups. It may involve installing quick disconnects on the STS, or aligning stops for the various components, or any other means of reducing the amount of work required by the current setups.

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[17] We estimate that the time lost on setup(s) could be reduced from an average of 30 minutes to a little over 7 minutes by doing the first two stages of SMED.

7. Material Handling Considerations

This section addresses material handling of WIP within the context of TOC management principles. Schonberger and Knod state that a tenet of Optimized Production Technology (OPT)[18] is that transfer batch sizes[19] should be decreased. This will allow for the next resource in the system to receive and start into work on the inventory sooner. Another advantage of decreasing transfer batch sizes is that the total production time is shorter and therefore the amount of WIP is smaller (Chase and Aquilano, 1989). But, more frequent transfers of inventory increases the material handling requirements. "Therefore, the transfer batch size is determined by a trade-off of production lead times, inventory reduction benefits, and costs of material movement." (Chase and Aquilano, 1989) Figure 7-1 shows the possible savings in repair turnaround time gained from decreased transfer and process batch sizes. The example also implies decreased WIP and increased material handling.

Figure 7-1 shows that when the process and transfer batch size is 100, it takes a total of 2100 minutes to process 100 items through the three different operations. This is because operation 2 cannot begin until all 100 items are

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[18]OPT is a scheduling system that contains underlying principles which were the precursors to TOC.

[19]A transfer batch refers to that portion of a batch that is moved to the next process.

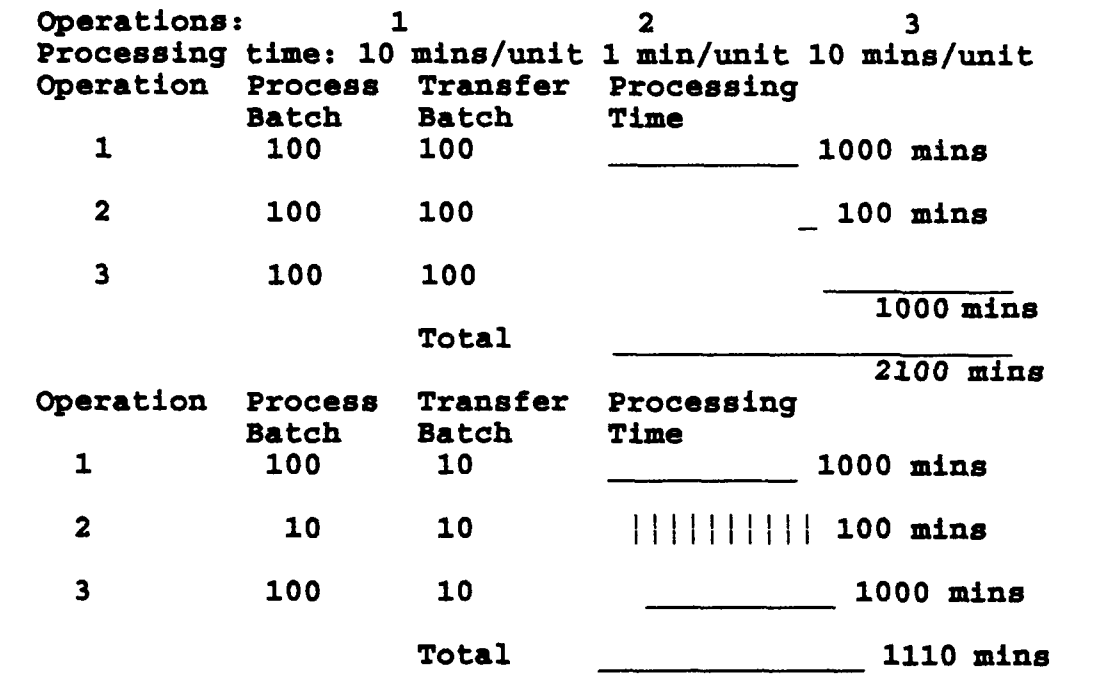

Figure 7-1. Effect Of Changing The Process And Transfer Batch Sizes On Production Lead Time (Chase/Aquilano, 1989)

transferred through operation 1. Likewise, operation 3 cannot begin until operation 2 has completed all 100 items.

By decreasing the transfer and process batch sizes, time in the system was almost halved (1100 minutes vice 2100 minutes) while WIP decreased from 100 to a maximum of 30 units. The reason for these decreases is that as soon as operation 1 processes 10 items, it transfers those items to operation 2. This allows operation 2 to begin processing at the same time as operation 1 continues working on the

remaining 90 items. Likewise, when operation 2 completes 10 items, it transfers those items to operation 3 allowing operations 2 and 3 to process at the same time. This parallel processing results in decreased repair turnaround time and decreased WIP. However, as mentioned above, the smaller batch sizes will also create additional material handling requirements as well as more machine setups.

Provided all non-bottleneck resources are subordinated to the bottleneck, there should be extra capacity available to devote to extra setups and increased material handling.

> Ideally, we would like to schedule all jobs on all machines while taking into account transfer lots and do it optimally. If the best sequence is such that no overlapping can be achieved -- e.g., if all machines have long queues, and every job has to wait -- then we may be actually better off without partial transfer lots. On the other hand, if we operate our plant efficiently, the only machines which should be allowed to accumulate considerable queues are bottleneck machines (to avoid starving them). Therefore, it is highly likely that transfer lots will be useful after all.(Trietsch, 1987)

And, from the same paper:

> Are there any circumstances under which the model will lead to transferring the items one by one? If the transfers are very inexpensive, our procedure will lead us to specify small transfers. If, in addition, the machines are balanced (i.e., have the same production rate), then the model will indeed indicate transfer lots of one, as in idealized JIT.(Trietsch, 1987)

With transfer batches minimized, the next step is to minimize queue times between work centers and work stations. Presently, P/Cs are responsible for movement of material between shops. If the P/C doesn't move a component as soon as it is finished at each work station, then the component

unnecessarily logs queue time which translates into longer repair TATs. No matter how good the P/Cs are, they will never be able to provide instantaneous response to multiple work stations. At times, P/Cs will be busy elsewhere or will have to adjust material movement due to shifting priorities. Whatever the case, some components will log extra queue time. Ironically, these shifting priorities, which encompass much of the P/C's time, result from un-synchronized operations. By synchronizing inductions to the rate at which the shop can produce (which is dictated by the bottleneck), much of the process complexity of material flow will be eliminated.

Process complexity can be defined as extra steps needed to recover from errors in the process (Fuller, 1985). Reducing process errors improves productivity. "Error reduction permits elimination of some process steps, such as disposition of faulty material, and reduction of the number of times that some process steps, such as re-work, need to be repeated." (Fuller, 1985)

In order to decrease the amount of time a component spends waiting between job steps we recommend the following: (1) Allow artisans to move components to the next step in the repair process upon completion of their step. This applies to all resources except the bottleneck. In the case of the bottleneck, the downstream non-constrained resource should pull from the bottleneck. (2) Provide as much as possible, a group technology (GT) or cellular layout to the shop floor.

GT allocates dissimilar machines or resources into cells to work on products that have similar processing requirements. The objective of GT is to gain the benefits of product layout in job-shop kind of production. (Chase and Aquilano, 1989) Each resource within the cell would then be responsible for fewer types of jobs.

Major benefits have been claimed for the application of cellular concepts, especially in relation to reduced throughput times and work-in-process. (Love and Bacekat, 1989) Additionally, better human relations, improved operator expertise, less material handling and faster production setups are products of GT. Reduction of paperwork requirements can be facilitated with GT and also the quick detection of quality problems naturally ensue. Finally, GT and SMED (discussed above) have a synergistic quality in that they both attack the same problem in different ways. In concert they would have a very powerful result.

Questions the NADEP would have to answer include: (1) Can all the resources needed for the repair process be put into close proximity to each other?; Or (2) could artisans working in the Shop 93302 be crossed trained to perform bearing changes, NDI, or helicoil replacement as opposed to sending the components to another building.

These changes would, of course, require policy and administrative procedural changes. However, the potential benefits far outweigh the cost of the changes. The time

components spend waiting between job steps in a manufacturing or job shop environment has been professed to be as high as 90% of the total lead time. (Bylinsky, 1983), (Spencer, 1991) If this is even partially true, the depot could achieve impressive gains in TAT reduction with improved layout and handling procedures.

D. SUBORDINATE THE NON-CONSTRAINTS TO THE SYSTEM CONSTRAINT

1. Drum-Buffer-Rope

In this section we will consider Drum-Buffer-Rope (DBR) (Goldratt and Fox, 1986) for scheduling the repair process which includes the STS. For this application, the key emphasis of the DBR scheduling technique is to keep the three STSs running at all times with components that will be sold soon. Time lost at the STSs is lost throughput for all components that are processed through them.

"Generating the drum" is the same as scheduling the constraint. As long as there is demand for the final products, the schedule or flow of components into the system should equal the capacity flow rate of the constraint. If the STSs are truly the bottleneck then, on average, the rate at which they process components should dictate the rate at which downstream work centers will receive WIP. It follows then that the rate at which the facility is able to "sell" or ship components is also dictated by the rate at which the STSs are able to process them. So, in effect, no matter where the

constraint is located in the system, shipping will also be constrained to the same rate of flow. Shipping's rate of flow will be the actual throughput for the system. Therefore, the "drum" we use to schedule material release into the system can very well be shipping (Trietsch, 1992). If shipping tended to hold onto RFI components vice shipping them immediately and finished goods built up, then a case could be made for shipping actually being the system's constraint. In this case we would apply Goldratt's Five Step Process to shipping. For now, we will use shipping as the system "drum".

The "rope" in our DBR system would be relatively simple to incorporate due to the linear repair flow of components which are processed through the STSs. Since the rope would now be tied from shipping to component induction, we would induct a component whenever we shipped one. Shipping a component would include "selling" a component back to ASO, "G" conditioning a component to the NSC, or BCM'ing a component for disposal. In other words, whenever a component leaves the system, we would induct one.

Induction and production schedules would not be formulated as they were prior to DBR. Actual loading of the work center by the P/C would now be in accordance with the shipping drum. For example, if a stab actuator was "sold" and another was "G" coded every day, then two stab actuators would be the daily induction schedule. The current level schedule procedure for critical components is still certainly

necessary, but quarterly schedules could be gradually increased as other exploitation techniques are incorporated.

For shops 93302 and 93303, "buffer" management could also be simplified. At present, the system constraint is the STS. Over time the constraint may change but this will not dictate a change in our buffer location. The rate at which the bottleneck (wherever it may be) produces will dictate the rate at which we can ship components. In this case, all that is necessary is to place a time buffer before shipping. A buffer of say two stab actuators generates the authority for the upstream resources to keep producing till the buffer of two is filled. When demand is greater than system capacity, the buffer will never be filled and upstream resources will continue to produce.

Another part of buffer management involves tracing back whenever unfilled buffer inventory occurs to the cause of disruption. With inductions equal to constraint capacity, occasionally additional disruptions would surface in the form of WIP building up before a resource (i.e., the bottleneck at the moment elsewhere). These build-ups should be investigated for the cause.

One benefit of DBR is that it schedules all resources according to the capacity of the system constraint. Therefore, excess capacity is available in the non-constraint resources. The extra capacity could be left idle in order to compensate for disruptions, used for additional setups in the

system, used for preventive maintenance, or used to assist in the movement of WIP through the system resources.

Another benefit of DBR is that WIP inventory levels decrease since system resources are not scheduled to capacity. A decrease in WIP would result in decreased TAT as discussed in Chapter II. Decreasing TAT can have two major impacts on the system which are very important in today's constrained budget environment; 1) increased readiness or 2) a decrease in the required amount of Ready-For-Issue (RFI) inventory (Trietsch, 1992). According to Fawcett and Pearson, WIP reduction also leads to better product quality, lower process costs, greater responsiveness, better due date performance, and improved communications. Goldratt adds the benefits of decreased space requirements and decreased overtime.

E. ELEVATE THE SYSTEM CONSTRAINT

The next step in the process is to elevate the system constraint. The purpose of this step is to take the system constraint and transform it into a non-constraint. For the Shop 93302, it may mean purchasing another STS. It may also mean hiring more artisans, or even re-structuring the organization.

In practice, what is commonly found is that as the system constraint is exploited it gradually becomes a non-constraint without purchasing another machine or hiring more workers. However, if the system constraint is fully exploited and more

capacity is needed, elevating the constraint is the next course of action.

For the shop 93302, it will probably not be necessary to hire more workers or buy another STS. Although the original F/A-18 single site survey called for six STSs, this survey was based on the current procedures used by the section. However, because there is considerable capacity just waiting to be freed up on those test stands, we suspect that when shop personnel exploit the STS it will no longer be the system constraint. When the shop reaches that point, it is time go to the last of Goldratt's Five Focusing Steps.

F. STEP 5, REPEAT STEPS 1 THROUGH 4. DO NOT ALLOW INERTIA TO BECOME THE SYSTEM CONSTRAINT

Each time a system constraint is eliminated, another system constraint will take its place. The purpose of this step is to keep the organization focused on constantly improving their operations, which ultimately keeps inertia from becoming the system's constraint. In order to have continual improvement (a key tenet of TQM philosophy), the five-step process must be continually repeated.

Management plays the key role in ensuring these steps are repeated. For an organization to stay on the path of continual improvement, management must lead the way; especially when the way requires changes in the organizational

mind set. The managers of Shop 93302 must become the "engine for change" which will lead to continual improvement.

VIII. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In this chapter we will summarize the results of our research and present conclusions and recommendations based on our analysis. We will also recommend areas for follow-on research which were beyond the scope of this thesis.

A. SUMMARY

Our goal in this paper was to determine the extent to which the Theory of Constraints (TOC) could be applied within a depot environment and its probable benefits. Chapter II described TOC managerial philosophy and principles. The production scheduling and inventory control technique Drum-Buffer-Rope (DBR) was also described as it relates to TOC. Chapter II additionally discussed decreased turn-around time (TAT) resulting from the application of TOC. Chapter III detailed the present organizational structure of NADEP NI. The focus was on middle to lower level management functions because these areas will initially have the most dynamic roles in any future implementation. Familiarity with Chapter III is critical to understanding the program management and functional management hierarchies that ultimately impact the artisan on the shop floor. Chapter IV described how the Depot presently plans, schedules and manages workload for the shops while Chapter V detailed how workload is controlled and

managed through the shops. Chapter VI described specifically how an F/A-18 Stabilizer Actuator is processed through the Depot repair shops. Chapter VII describes our application of TOC and DBR to a specific area of the Depot. We described how TOC could be used at NADEP NI to identify a constraint within the Component Section. We suggested ways to save time on the Servocylinder Test Station (STS) (Shop 93302-Hydraulic Component Repair) which could be used to increase throughput, decrease repair TATs (therefore increase readiness), and ultimately enhance customer service. We additionally described methods to harness the excess capacity within Shops 93302 and those others (non-constraint resources) involved in the repair process. And, finally, we applied a method (modified DBR) of controlling the inventory flow through the repair process. The method appears well suited to the depot environment.

B. CONCLUSIONS

We are convinced that the operations of Shop 93302 and 93303, and ultimately the depot operation, would benefit by using the Theory of Constraints (TOC) management principles. TOC is readily adaptable to the industrial repair environment of a Naval Aviation Depot. The potential benefits of implementing TOC in a NADEP include: (1) increased throughput; (2) decreased TAT; (3) increased flexibility in meeting

shifting customer needs; and (4) decreased inventory and operating expense.

While TOC is not the only "new" management technique available, it is very attractive for a number of reasons. For one, it focuses command attention on what is truly important; reducing repair TATs and profitable throughput now and in the future. Everything else is secondary. This is in opposition to the "preaching of cost accounting" which encourages managing hundreds of cost minimizations. Another benefit of TOC is that scheduling is simplified. TOC also blocks harmful managerial practices such as encouraging capacity level production in all shops. And, since TOC is a management practice, it doesn't require any additional software or major capital outlay.

We believe TOC, with it's "Five Focussing Steps", is an effective method of improving any process and, if applied in an iterative fashion, will be capable of spurring continuous improvement. But as Goldratt observed:

> ...we shouldn't fall into the trap of ever believing that at last we see the ultimate light. We are dealing with management science and science definitely doesn't believe in truth, only in validity. Everything in science is open to question, where truth belongs to the realm of religion. That is why the Theory of Constraints concentrates on the thinking process, on the verbalization of intuition and regards its applications not as ultimate solutions, but at most as powerful ones.
>
> Since truth does not exist in science, ultimate solutions do not exist. The highest rank given to a solution is "powerful". (Goldratt, 1990b)

C. RECOMMENDATIONS

We recommend implementing TOC throughout all aspects of NADEP NI. This would certainly not be easily achieved since the Theory of Constraints differs greatly from generally accepted management beliefs. Goldratt discusses the roadblocks to implementation of TOC at length in his book on TOC. However, once understood, the theory conveys a common sense, intuitively correct managerial framework. TOC breaks down the ponderous task of managing a complex process into manageable steps, thereby relieving the manager of the sense of being overwhelmed.

Once management determines where to focus its improvement efforts, the next logical question is, "Which improvement do we implement first?"; i.e., "How do we prioritize the improvements?" There are several ways to do it, but we recommend comparing the ratios of the expected benefits (i.e., increased throughput) and the expected costs for each improvement. Then rank them from highest to lowest. The improvement with the highest value should be implemented first. This way of prioritizing considers both benefits and costs.

A necessary pre-condition for successful implementation of TOC is top management support. Without it, any improvements that might result would, at best, be short-lived.

Once top management pledges its support, the initial step would be to gain understanding and acceptance of TOC

management principles from everyone else involved in the process. This includes all middle management and shop supervisors affected by the results of the program. An environment of complete trust, where erring is acceptable, is necessary (this is no different from Deming's 14 steps for TQM; indeed, we recommend TOC as a part of the TQM program, not as a substitute). In order to facilitate this and for continuity purposes there should be a cadre of individuals somewhere in the command who are knowledgeable in TOC and available to provide education as necessary.

As an important first step we suggest initiating a pilot program within Shops 93302 and 93303; or some other process within the Depot with resources which are dedicated to a small number of products. Productivity gains in one area would do much to gain acceptance elsewhere. In particular, we are sure that workers on the floor will quickly be able to come up with more ideas.

Our specific recommendations for Shop 93302 are:

- Implement a transfer batch size of 1. Acquire pushcarts for components that cannot be moved easily by one person.
- Change policy and procedures for moving components between work stations; i.e., artisans should move the components vice the production controller or material expediter. This applies to all work stations except the STS. The next downstream resource would be responsible for pulling components from the STS.
- Reduce setup time on the STS to 7 minutes.
- Cross-train artisans on the STS.

- Synchronize the induction rate to shipping. This would effectively tie inductions to the constraint resource's production rate.
- Use TOC to enable shop personnel to generate additional ideas for improvement.

Once the depot is satisfied with the pilot program results and comfortable with the TOC style of management, a depot-wide implementation could begin. The depot should first analyze its business in terms of **THROUGHPUT**. This would be similar to **IDENTIFYING THE CONSTRAINT** but on a global scale. Based on constraints from NAVAIR, the industry structure (in particular the threat of new private sector entrants into the industry) and the lack of reliable service from its military suppliers, the depot should concentrate on how to maximize its profitable throughput, now and in the future.Next, the remainder of Goldratt's Five Focussing Steps should be applied on a global basis (the five-step process was detailed in Chapter II and is an iterative process providing continuous improvement).

As we mentioned at the end of the previous section, by itself, TOC can not optimize productivity. However, it is a powerful management tool that can significantly improve the operations at the NADEP.

D. AREAS FOR IMMEDIATE FURTHER RESEARCH

1. Determine whether there are any components which are presently processed through the STS which could be offloaded to other resources.

2. Investigate how to alleviate repair parts shortages in the depot in an attempt to reduce the number of components that are "G" conditioned.

3. Determine a procedure for performing a cost/benefit analysis of setup time reductions on capacity constrained resources in the depot. We suggest starting with Shop 93302.

APPENDIX A: ACRONYMS

AMP	Analytical Maintenance Program
APML	Assistant Program Manager for Logistics
ASO	Aviation Supply Office
ATE	Airborne/Automatic Test Equipment
AVDLR	Aviation Depot Level Repairables
BCM	Beyond the Capability of Maintenance
BM	Buffer Management
BOC	Business Operating Center
CCC	Component Control Center
CFA	Cognizant Field Activity
DBR	Drum Buffer Rope
DMISA	Depot Maintenance Interservice Agreement
EDD	Estimated Delivery Date
ES	Equipment Specialist
ESC	Executive Steering Committee
F/E	F and E Condition (code for broken items)
FMS	Foreign Military Sales
IET	Industrial Engineering Technician
IM	Item Manager
LED	Local Engineering Directives
LEF	Leading Edge Flap
LVDT	Linear Variable Differential Transformer

MAPPER	Maintaining and Preparing, Producing Executive Reports
MCC	Material Control Center
MCRC	Master Component Rework Control
MDR	Master Data Record
MICO	Maintenance Intra/Interservice Coordinator
NADEP	Naval Aviation Depot
NADOC	Naval Aviation Operating Center
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
OPT	Optimized Production Technology
P/C	Production Controller
P/E	Planner/Estimator
PMA	Program Manager Air
PMTO	Program Management Training Office
PROBE	Production Requirements of B and E[20]
PS	Production Status
QAS	Quality Assurance Specialist
RAMEC	Rapid Action Minor Engineering Change
RFI	Ready-for-Issue
RFU	Ready-for-Use
RSI	Retail Stock Inventory
STS	Servocylinder Test Station
TAT	Turn-Around-Time

[20] B and E coded items are now F and E condition coded items (Endrizzi, 1992).

TOC	Theory of Constraints
TQM	Total Quality Management
TYCOM	Type Commander
UADPS	Uniformed Automated Data Processing System
UICP	Uniform Inventory Control Program
VRT	Voyage Repair Team
WIP	Work-in-Process
WIPICS	Work-in-Process-Inventory-Control-System

APPENDIX B: COMMODITY PROGRAM BUILDING LAYOUT

Figure B-1 shows the Commodity Program building layout. Shops 93302 and 93303 (hydraulic component repair) are located in Building 341. Hydraulic components are routed primarily through Building 341 or 472.

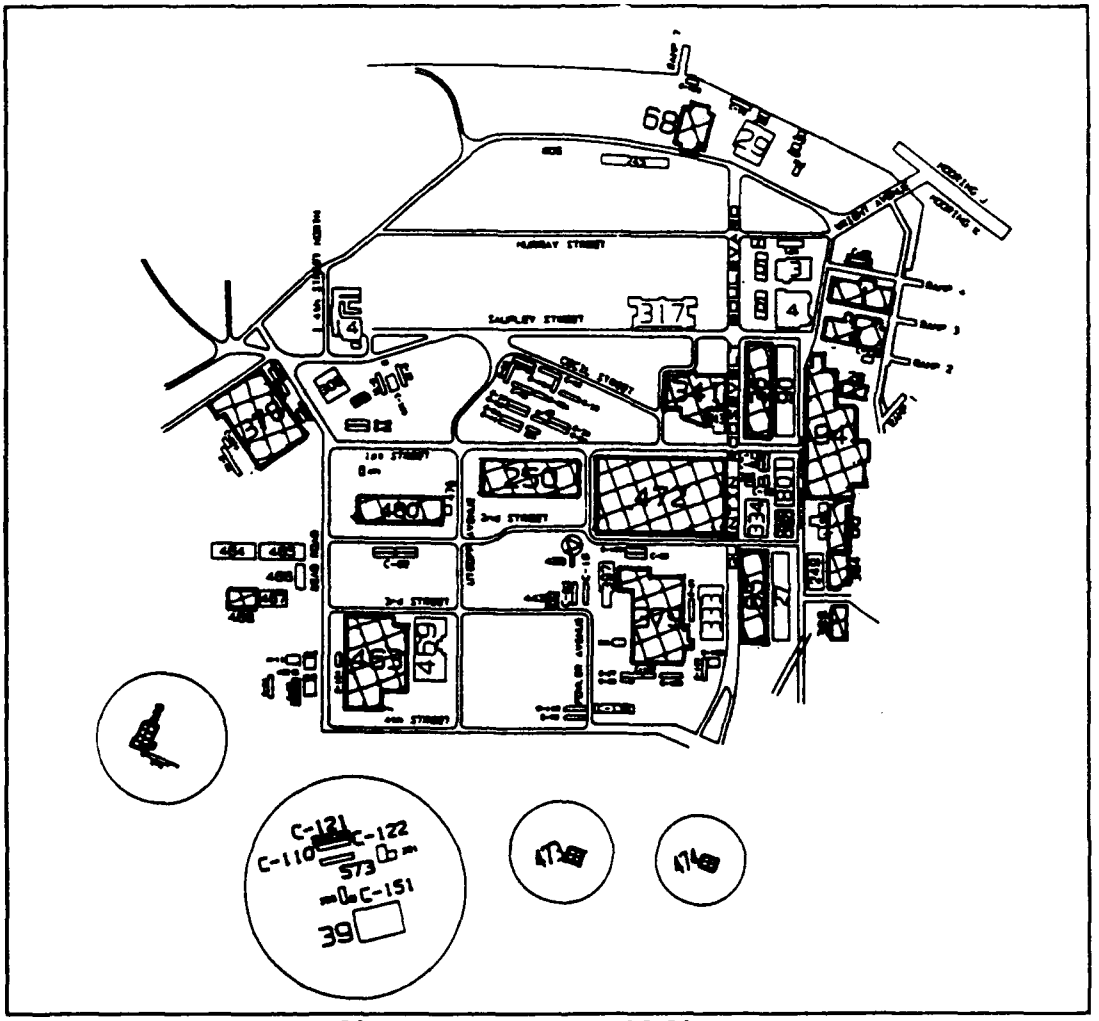

Figure B-1. Commodity Program Building Layout.

APPENDIX C: BUILDING DIAGRAM/SHOP LAYOUTS

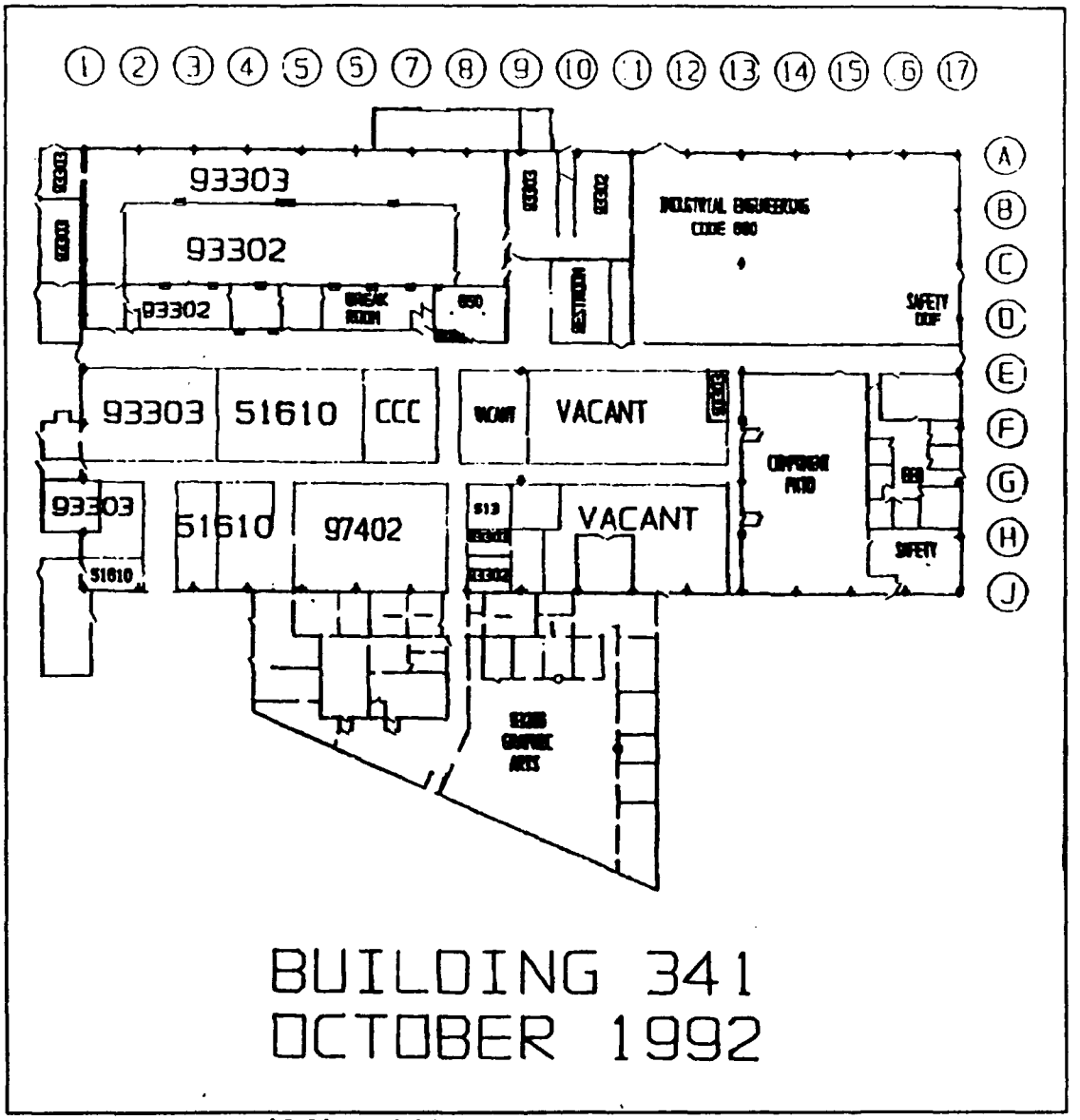

Figure C-1. Building 341 Layout

Figure C-1 shows the shop layout for Building 341.

APPENDIX D: SERVOCYLINDER TEST STATION

The STS is a self contained, automatic hydraulic test station. It is used to test various F/A-18 aircraft hydraulic components within Shop 93302. It consists of four major sub-assemblies (see Figure B-1). The depot currently has three of these test stands.

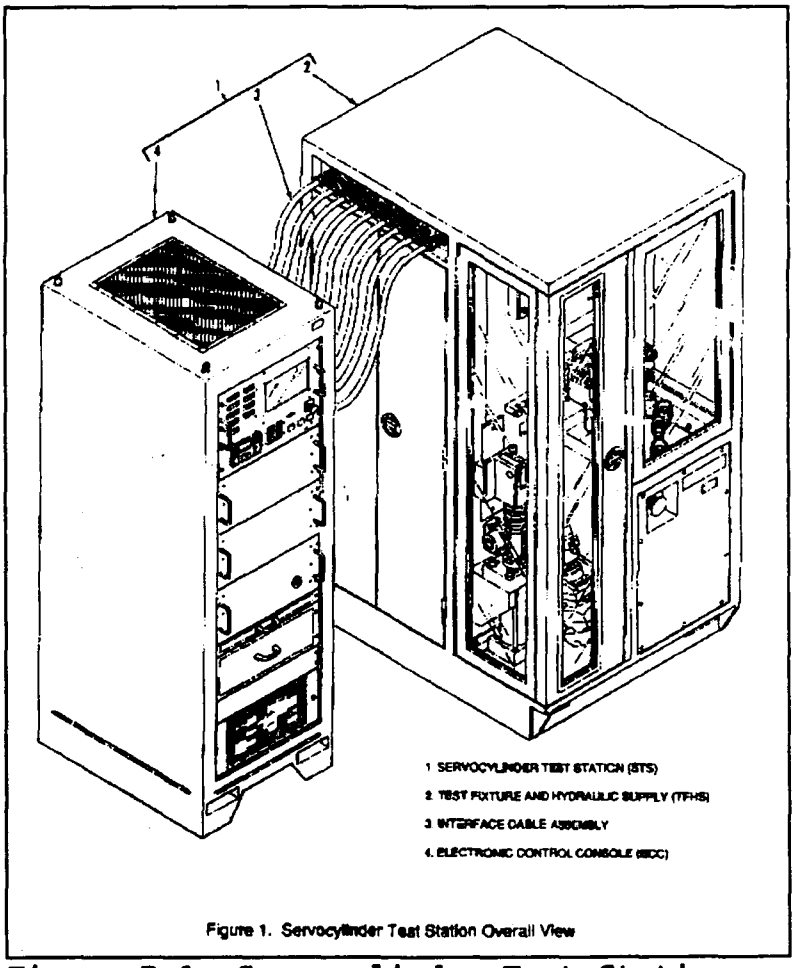

Figure B-1. Servocylinder Test Station

APPENDIX E: HORIZONTAL STABILIZER HYDRAULIC SERVOCYLINDER

Figure C-1 shows a Horizontal Stabilizer Hydraulic

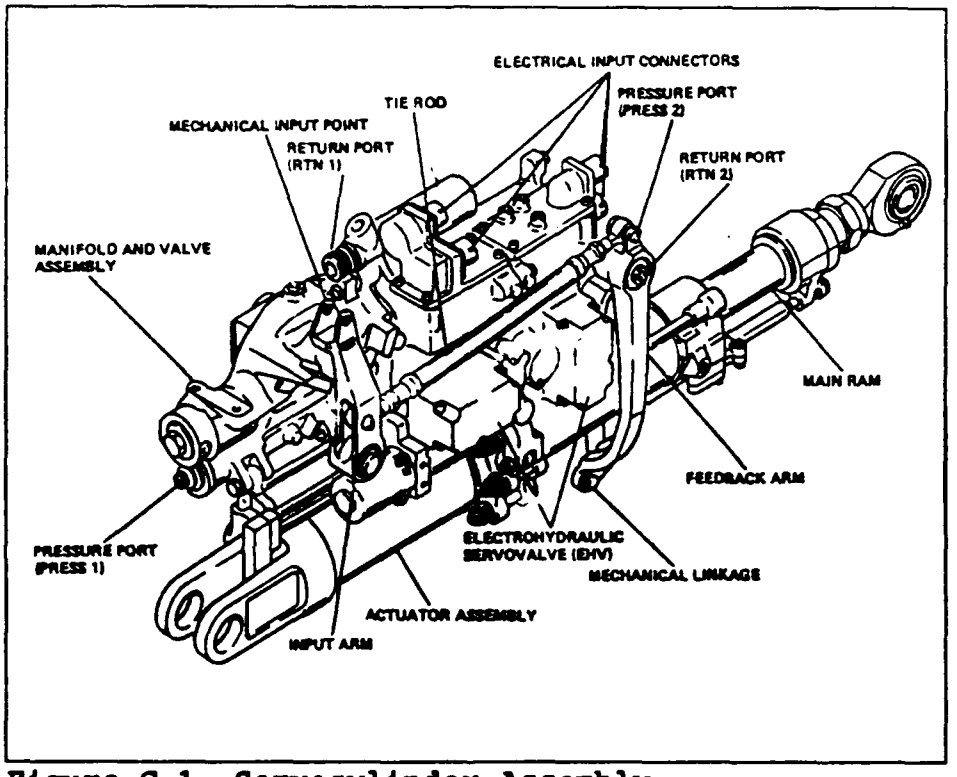

Figure C-1. Servocylinder Assembly.

Servocylinder for an F/A-18 aircraft. This component is 36.3 inches long, 14.8 inches high, and 6.7 inches wide. It weighs 74.75 pounds.

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